TM 1-411

WAR DEPARTMENT TECHNICAL MANUAL

AIRPLANE HYDRAULIC SYSTEMS

WAR DEPARTMENT • 8 MAY 1944

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SECTION I

HYDRAULIC PRINCIPLES AND THEIR APPLICATION

1. GENERAL. Hydraulics may be defined as that branch of science which deals with the study of liquids. To understand hydraulics as applied to airplane hydraulic systems, it is necessary to understand some of the basic laws and properties of liquids. It is also necessary to understand clearly the meaning of the following terms:

a. Force. Force is any push or pull on an object. In this manual, force will be expressed in pounds (lbs).

b. Pressure. Pressure is the amount of force distributed over each unit of area. In this manual, pressure will be expressed in pounds per square inch.

2. LIQUIDS. A liquid is any fluid whose particles have freedom of movement among themselves but have no tendency to separate. In other words, a liquid has definite volume but no definite shape. If a liquid is put into a container, it will assume the shape of the container.

a. Expansion and contraction. In general, liquids expand when they are heated, and contract when they are cooled. If a liquid is confined so that it cannot expand when it is heated, pressure on the walls of the confining vessel will increase.

b. Incompressibility. Liquids are practically incompressible. It is true that the application of large forces will cause a very small decrease in volume. But this decrease is not large enough to be of practical importance.

3. TRANSMISSION OF PRESSURE IN LIQUIDS. a. Principle. Pressure applied to a confined liquid is transmitted undiminished in all directions. This pressure acts at right angles to the walls of the container and exerts equal forces on equal areas.

b. Application. The principle stated in a above is illustrated in figure 1.

(1) A force of 5 pounds is applied to piston *A*, which has an area of ½ square inch. This is equivalent to applying a force of 10 pounds to a whole square inch. Therefore, the pressure created in the liquid will be 10 pounds per square inch. In accordance with the foregoing principle, the pressure acting on the face of the piston *B* will be 10 pounds per square inch. Since

the area of piston *B* is 10 square inches, the force acting on piston *B* will be 100 pounds.

(2) If piston *B* is made larger, the force acting on it will be increased. Also, if piston *A* is made smaller, the pressure created in the liquid will be greater, and the force acting on piston *B* will be increased.

c. Mechanical advantage. (1) In the foregoing example the force produced at *B* is greater than the force applied at *A*. This increase is directly proportional to the size of the cylinders. The force produced at *B* divided by the force applied at *A* is called the "mechanical advantage" of the system.

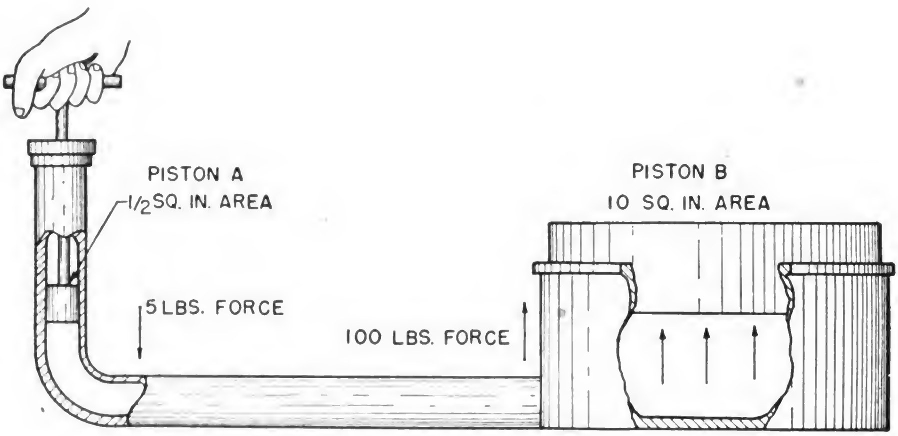


Figure 1. Simple hydraulic mechanism.

(2) Since the volume of liquid forced out of cylinder *A* is equal to the volume forced into cylinder *B*, piston *B* will move a shorter distance than piston *A*. Piston *B* will also move slower than piston *A*. Thus, speed and distance must be sacrificed to gain force. The loss in speed and distance is inversely proportional to the size of the pistons. In figure 1, piston *B* is 20 times as large as piston *A*. Therefore, it will move one-twentieth as far and one-twentieth as fast as piston *A*.

d. Use. The foregoing application of the principle of transmission of pressure in liquids is the basic principle of operation of all aircraft hydraulic systems. Light oil confined in tubing is used to transmit pressure from one point to another on the airplane. Except for friction (which is slight), this pressure is the same at both ends of the tubing, regardless of the length of the tube or the number of bends. By connecting the tubing to a cylinder whose area is larger than that of the tubing, and by inserting a piston in the cylinder, the force applied at the end of the tubing may be increased. Oil forced into the tubing at a certain rate will move the piston at a slower rate but with a greater force. By means of a piston rod, the motion of the piston and the force acting on it may be transmitted to any mechanism which is to be operated.

4. PURPOSE OF HYDRAULIC SYSTEMS. The basic purpose of the hydraulic system on a modern airplane is to operate certain mechanisms for the pilot and crew. Among these mechanisms are automatic pilots, landing gear, wing flaps, cowl flaps, diving flaps, bomb doors, brakes, gun chargers, gun turrets, and windshield wipers.

5. ELEMENTARY HYDRAULIC SYSTEMS. The development of a simple hydraulic system is shown in figures 2 to 8, inclusive. Since each example contains one or more units than the preceding one, each must be clearly understood before the next one is studied.

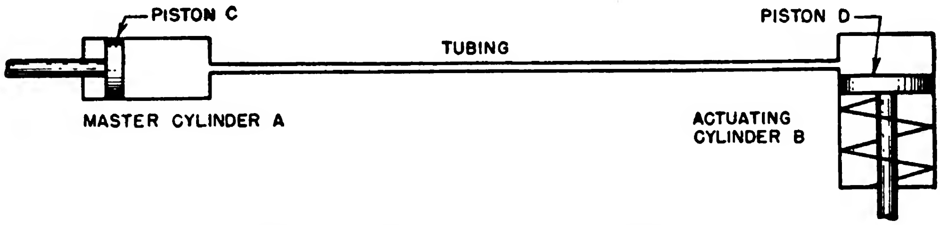


Figure 2. Elementary hydraulic system.

a. Development. (1) Figure 2 shows a master cylinder *A* connected to an actuating cylinder *B* by means of tubing. A master cylinder is a unit which transforms force into pressure. An actuating cylinder is a unit that transforms this pressure into a force acting to operate a mechanism. If the cylinders illustrated are filled with oil and the master-cylinder piston *C* is forced toward the right, oil under pressure will enter the actuating cylinder *B* and push piston *D* down against the force of the spring. When the force is removed from the master-cylinder piston, the spring in the actuating cylinder will force piston *D* up, thereby returning the fluid to the master cylinder. This type of system can be used only where the lead on the rod attached to piston *D* is light enough to be moved by the spring. Another limitation is the fact that piston *D* will be moved only a short distance, because it is much larger than piston *C*. If piston *D* must be moved a relatively long distance, there must be a source of oil (a reservoir) which will replenish the oil driven out of the master cylinder.

(2) In figure 3, a reservoir has been attached to the master cylinder. This reservoir must be vented to the atmosphere so that air can enter or leave it as the fluid level in the reservoir changes. Now, with this system as it is, if the force on piston *C* were removed, the spring-loaded piston *D* would rise and force oil out of cylinder *B* back into cylinder *A*. This flow would prevent oil from flowing down into cylinder *A* from the reservoir. Therefore, a check valve must be placed in the line between the two cylinders. A check valve is a device that will allow flow in one direction but not in the other. This valve will allow oil to flow *to* the actuating cylinder but not *from* it. Now as piston *C* moves to the left, it draws oil from the reservoir into the master cylinder. However, if piston *C* were again moved to the

right, the oil would follow the path of least resistance and return to the reservoir. To prevent this, a check valve must be placed in the supply line between the reservoir and cylinder *A*.

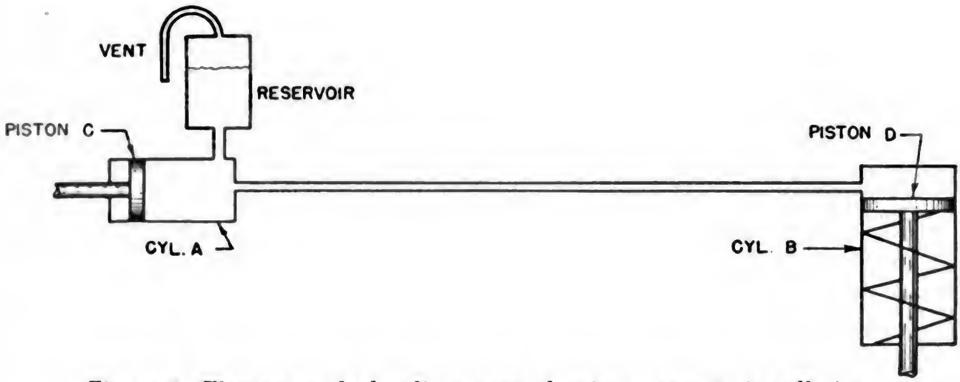


Figure 3. Elementary hydraulic system showing reservoir installation.

(3) Figure 4 shows the system with the check valves added. Movement of piston *C* to the right and left alternately will pump oil into cylinder *B*. The addition of the check valves and the reservoir has changed the master cylinder to a single-action hand pump. However, this system would be impractical, because once piston *D* was forced down, it would be held down by

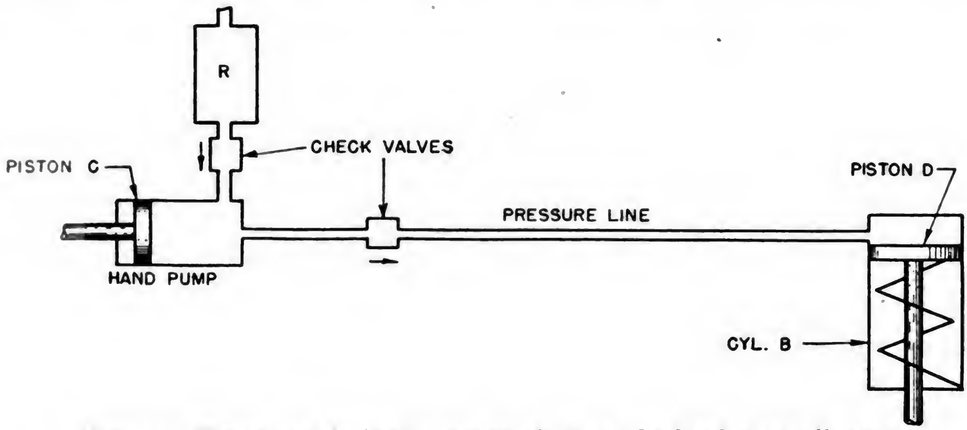


Figure 4. Elementary hydraulic system showing check-valve installation.

the oil, which cannot escape because of the check valve. It is, therefore, necessary to install a selector valve (fig. 5) in the system, and also a return line to the reservoir. A selector valve is a device by means of which flow can be turned in any of several directions. When the selector valve is in the position shown in figure 5, oil from the pump (master cylinder) is directed into cylinder *B* and the piston is forced down. If the inside of the valve is rotated 90° clockwise, as shown by the dotted lines in the diagram, the top of cylinder *B* is connected to the return line through the drilled passage in the rotor. Oil is then free to escape from cylinder *B* through the return line to the reservoir, and the spring can move piston *D* up to its original position.

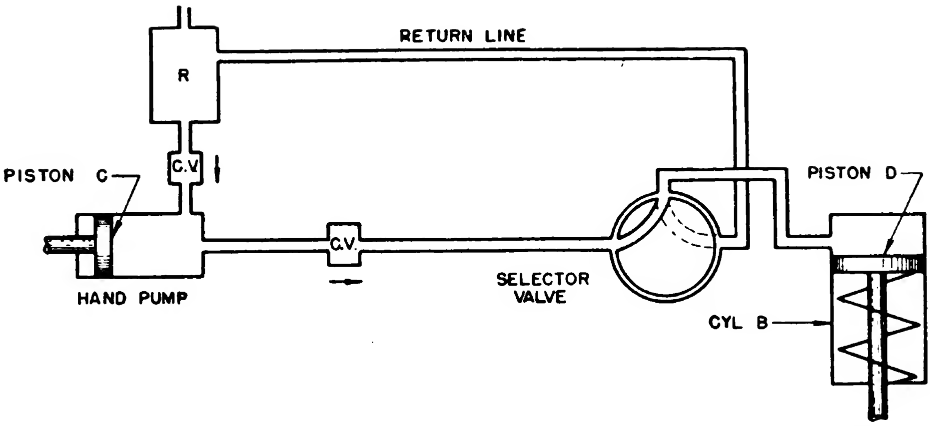


Figure 5. Elementary hydraulic system showing two-port selector-valve installation.

(4) If two-way operation of some heavy mechanism is desired, the system in figure 5 would not be practical. Piston *D* could be moved down by the pump, but the spring would not be strong enough to overcome the weight of the mechanism. It is therefore necessary to install a port in the bottom end of cylinder *B*. When oil under pressure is directed into this port, piston *D* will be forced up. To direct oil from the pump into either end of cylinder *B* will require a different type of selector valve. The selector valve shown in figure 5 has only three ports. Since there will now be two lines connected to the actuating cylinder, a selector valve with four ports must be used. This type is usually called a "four-way" valve. The system with these additions is shown in figure 6.

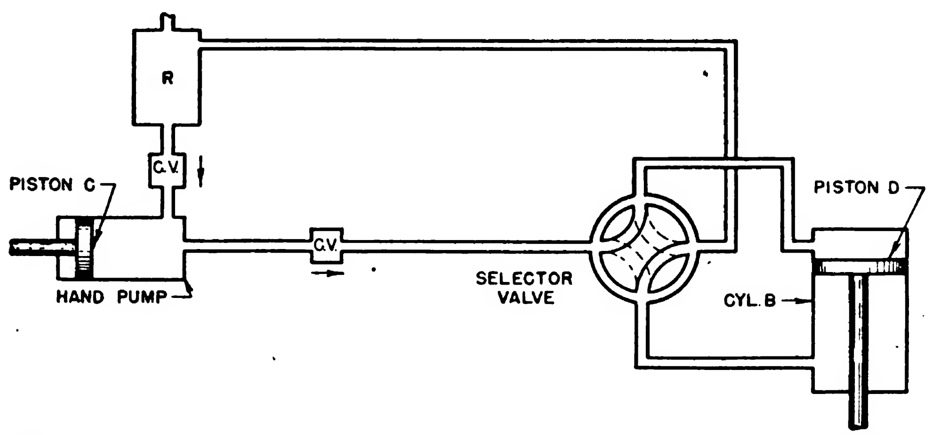


Figure 6. Elementary hydraulic system showing four-port selector-valve installation.

(5) As may be seen in figure 6, oil may be directed to either end of cylinder *B* by changing the positions of the drilled passages in the selector-valve rotor. The pressure line and the return line must be connected to opposite ports on the selector valve. This system could be used to operate a mechanism, but it has several disadvantages. The amount of oil delivered during each cycle of the hand pump is comparatively small. Operation of

the landing gear or any other mechanism having large actuating cylinders would, therefore, take considerable time and effort on the part of the pilot if he worked the pump himself. The installation of an electrically driven power pump will eliminate this undesirable feature.

(6) The system, to which a power pump has been added, is shown in figure 7. The pilot can now move the mechanism by setting the selector valve in the desired position and starting the power pump. However, unless

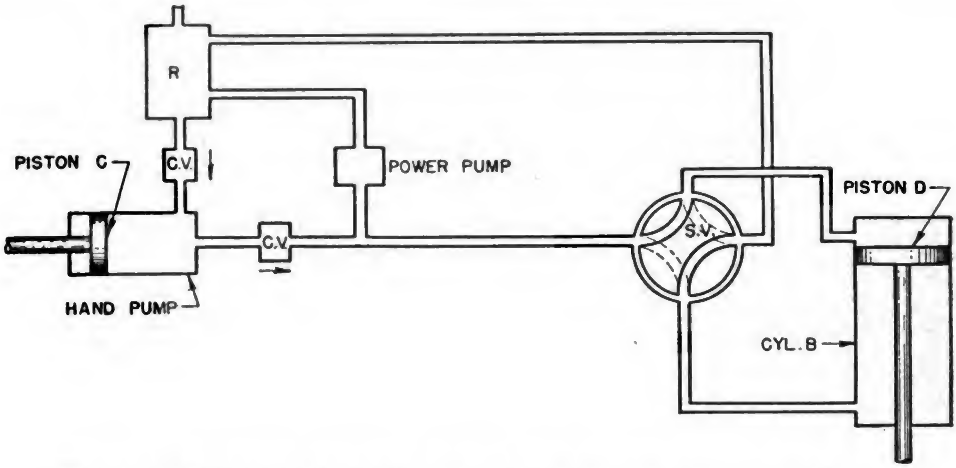


Figure 7. Elementary hydraulic system showing power-pump installation.

the pump is stopped the instant the mechanism reaches the end of its travel, pressure will build up very rapidly. This high pressure would either rupture some part of the system or damage the pump unless some unit were added to limit the pressure that might be developed. Hence a relief valve (a valve which opens and relieves pressure when the pressure reaches a certain value) must be installed between the pressure and return lines. However, the system in figure 7 would be impractical also because the hand pump, retained for emergency operation and ground checking, would be useless, since the

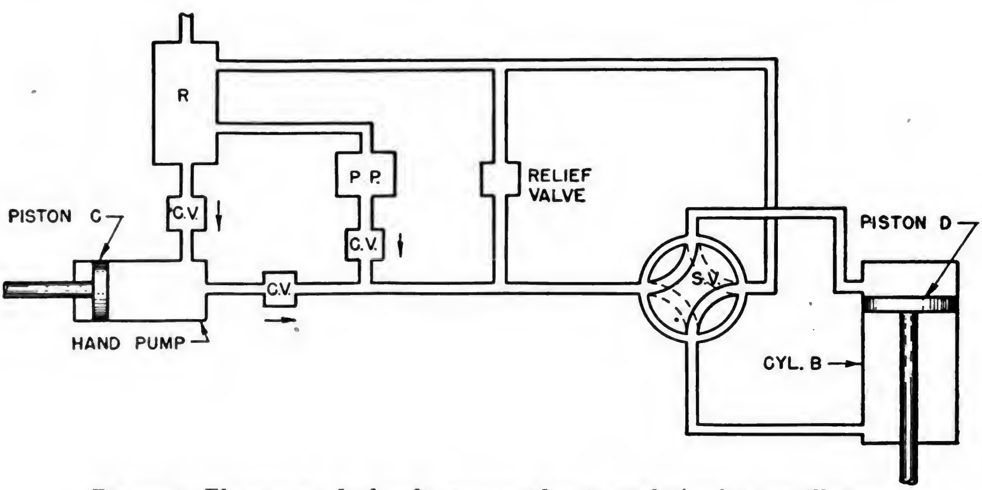


Figure 8. Elementary hydraulic system showing relief-valve installation.

output of the hand pump would turn the power pump backward and return fluid to the reservoir. To prevent this, a check valve must be installed between the power pump and the pressure line. Figure 8 shows a system in which a relief valve and a check valve have been installed.

(7) A simple, workable hydraulic system has now been developed. When piston *D* reaches the end of its stroke and pressure builds up, the relief valve will be "kicked out" and the output of the power pump will be bypassed to the return line. Pressure will be retained in the pressure line when the pump is running, because the pump must continuously develop enough pressure to overcome the force of the spring in the relief valve. When the pump is stopped, pressure will be trapped in the pressure line by the check valves. Additional selector valves and actuating cylinders may be added to the system to operate other mechanisms.

6. CHARACTERISTICS OF HYDRAULIC EQUIPMENT. Since weight elimination is vital in present-day airplane design, most aircraft hydraulic equipment is made of aluminum alloy capable of withstanding high fluid pressure. Movable parts of aircraft hydraulic equipment are constructed of hard molybdenum steels in order to withstand wear and corrosion. The various units are connected by either rigid or flexible tubing. Where rigid tubing is used, connections are usually made with three-piece flared tube fittings. Necessity demands that hydraulic equipment be reliable, efficient, and compact, and that it require a minimum amount of maintenance.

SECTION II

ENERGIZING AND ACTUATING UNITS

7. GENERAL. a. A hydraulic unit is a device which has a definite job to perform in the system. A hydraulic energizing unit is a device used to transform mechanical force into liquid pressure. It is the unit which produces pressure and circulates the liquid in the system. A hydraulic actuating unit is a device used to transform liquid pressure into mechanical force and cause a mechanism to be moved.

b. It should be remembered that each unit discussed in this manual is to be taken as representative of the types in use. Each type may vary in appearance and construction, but its basic operating principle will be the same. The drawings are used to illustrate the discussion and are not intended to be detailed drawings of particular units.

c. Since the reservoir supplies oil to the energizing units and the filter keeps this oil free of impurities, the reservoir and the filter will be discussed first.

8. RESERVOIR. a. Purpose and use. An adequate supply of fluid for the hydraulic system is stored in the reservoir shown in figure 9. It is usually located at the highest point in the system, so that the pumps will be primed at all times. Fluid flows from the reservoir to the hydraulic pumps, is forced by them throughout the system, and eventually returns to the reservoir. The reservoir not only supplies the operating needs of the system, but also replenishes fluid lost through leakage. Furthermore, the reservoir serves as an overflow basin for excess fluid forced out of the system by thermal expansion (expansion of fluid due to temperature change), by the accumulators, and by piston-rod displacement. The reservoir also furnishes a place for the fluid to purge itself of air bubbles which enter the system at certain operating units. Foreign matter picked up in the system may also be separated from the oil in the reservoir.

b. Description. Reservoirs are always vented to the atmosphere. The vent line may contain a check valve to prevent loss of fluid during inverted flight. A filter screen and a sediment trap are usually incorporated in the unit. The screen may be located in the reservoir itself or in the filler neck. The outlet to the power pump is either located higher than the outlet to the hand pump or is connected to a standpipe. This arrangement insures a

supply of fluid sufficient to operate the emergency hand pump even though the fluid supply to the power pump has been depleted. Reservoirs are sometimes equipped with a fluid quantity gauge to be used as a guide in filling. Technical Orders should be referred to for proper filling procedure.

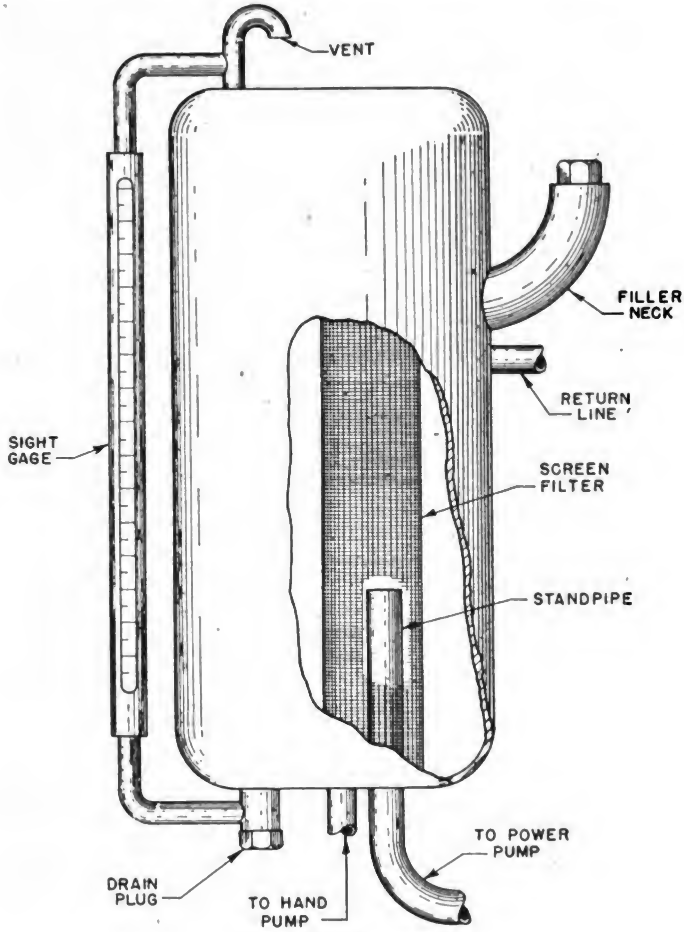


Figure 9. Reservoir.

c. Inspection and maintenance. The oil level should be checked periodically. The reservoir should be visually inspected for leaks and if a leak due to a faulty gasket is found, the gasket must be replaced. Screens should be cleaned and sumps should be drained frequently.

9. FILTERS. a. General. The purpose of a filter is to remove foreign matter from the oil. If this material is not removed, it may cause failure of the entire hydraulic system by causing the failure of some unit. Filters may be divided into two general classes: those which employ the principle of edge filtration, and those which employ the principle of screening.

b. Cuno filters. Filters of the Cuno type (fig. 10) employ the principle of edge filtration. They consist of a head, a sump or housing, and a cartridge or filtering element.

(1) The head serves as a base to which the cartridge and housing are fastened. At the bottom of the housing is a drain plug. The cartridge consists of a stack of spoked wheel-shaped disks separated from each other by spacers. Both disks and spacers are rigidly mounted on a spindle which can be turned. Located beside this stack of disks is a stack of cleaner blades mounted on a fixed rod. These blades are mounted in such a way that each blade enters the space between adjacent disks far enough to extend beyond the inner edges of the rims of the disks. These blades are fixed to the cleaner blade rod and cannot turn.

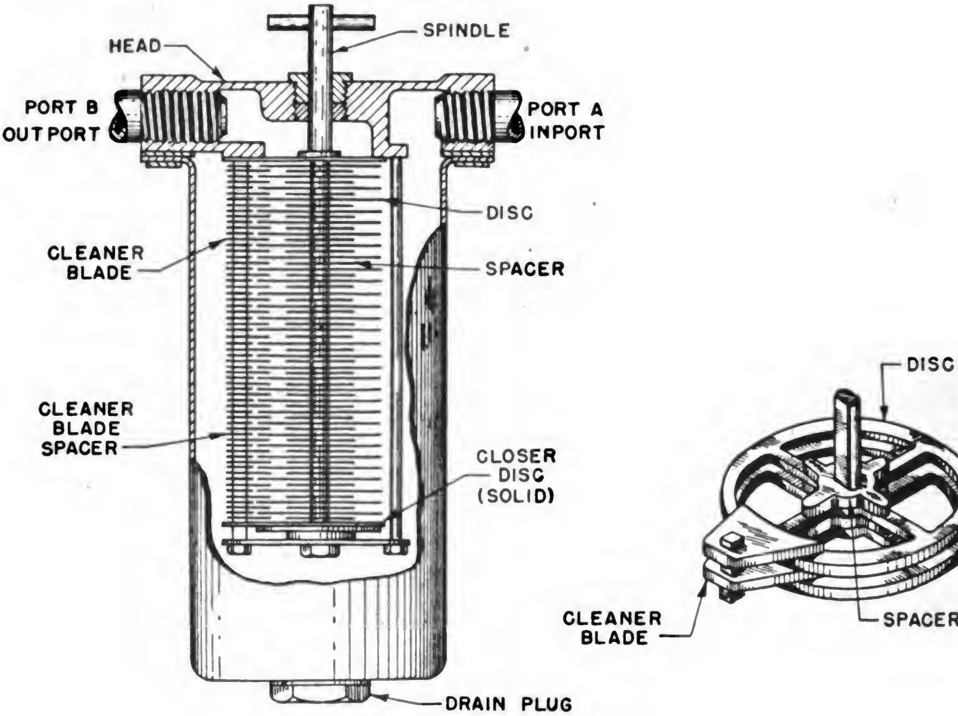


Figure 10. Cuno filter.

(2) Fluid entering the housing through port *A* (fig. 10) surrounds the cartridge. Before it can reach the outport *B* in the head, it must pass inward between the disks and then upward in the space between the spokes of the disks. Solids too large to pass between the disks remain on the surface of the cartridge until the disks are rotated. One complete revolution of the disks past the fixed cleaner blades removes all foreign matter from the cartridge. As solids are dislodged from the cartridge, they fall to the bottom of the housing. This cleaning operation can be accomplished while the filter is in operation.

(3) In some filters, a bypass relief valve is installed between the outport and the inport. The purpose of this valve is to relieve pressure in the filter if it becomes clogged so that oil cannot pass through. When the pressure reaches a certain point, the valve opens and allows fluid to pass from the inport directly to the outport.

c. **Screen type filters.** Filters of the screen type employ the principle of screening. They consist of a head, a housing, and a filtering element or cartridge. Some units incorporate a ball check bypass valve in the cartridge.

(1) The head is threaded to screw on the housing and contains the outport *A* (fig. 11). The port *B*, through which oil enters the unit, is located in the end of the housing. The cartridge consists of a perforated metal cup which

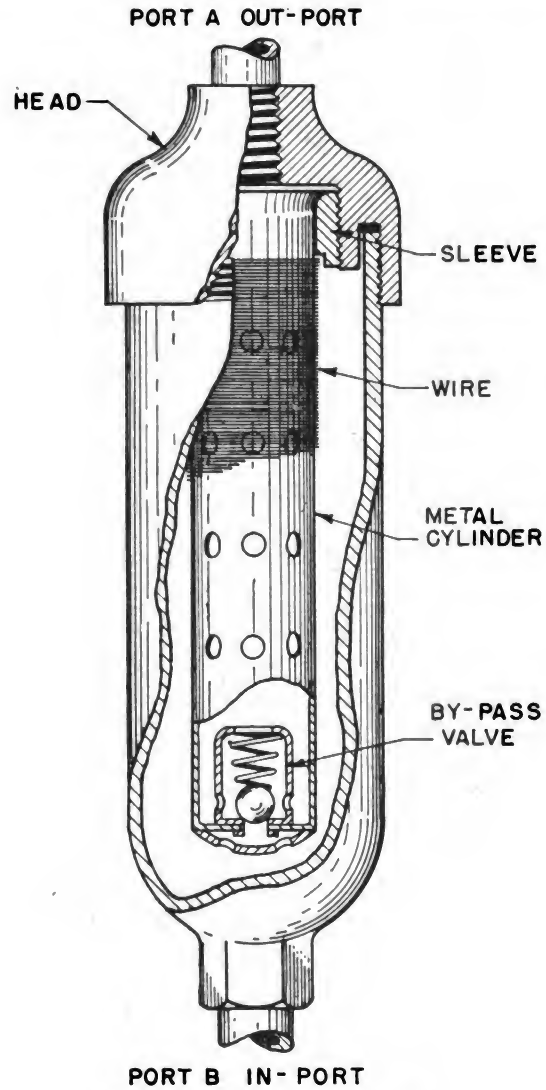


Figure 11. Screen type filter.

is closely wound with very fine wire. One end of this cup is flanged. The cartridge is mounted on the head by means of a sleeve which slips over the cup and screws into the head.

(2) Oil entering the housing through port *B* surrounds the cartridge. Before this oil can reach port *A*, it must pass between the closely wound turns of wire and into the cup. Solids too large to pass between the turns of wire are separated from the oil and remain on the cartridge until the unit is

cleaned. Filtered oil passes out of port *A* and into the system. This screen type filter must be removed from the system and disassembled before it can be cleaned. However, some screen type filters are equipped with a rotating blade and may be cleaned while in operation.

d. Maintenance. All types of filters must be cleaned at regular intervals to insure proper operation. It is imperative that filters be cleaned at the proper times. Failure to do so will result in dirty oil and probable failure of the entire hydraulic system.

(1) The Cuno-filter cartridge may be cleaned by rotating the handle one complete revolution in each direction. Accumulated solids may be removed from the housing by removing the drain plug. The unit must be disasssembled for complete cleaning. After disassembly, the unit should be thoroughly washed with kerosene or a mixture of carbon tetrachloride and benzol. Care should be exercised to prevent harm to the cartridge when removing it from and inserting it into the housing. Packings and gaskets may be replaced in case of leakage at joints.

(2) The screen type filter which does not have a rotating cleaner blade must be removed from the system for cleaning. After removal, break the safety wire, unscrew the head, and remove the cartridge. Then thoroughly wash the unit in a suitable solvent.

10. POWER PUMPS. a. Purpose and use. The primary energizing unit of the hydraulic system is the power pump. It is the unit which normally delivers oil under pressure for the actuating units. A power pump may be driven by an electric motor or by the airplane engine. If engine-driven, the pump is mounted on the engine accessory section. Most power pumps have a shear pin or shear section incorporated in the drive mechanism which will free the pump in case of overload.

b. Gear type pump. Figure 12 is a schematic drawing of the gear type pump. This unit consists of two meshed gears *A* and *B* which revolve

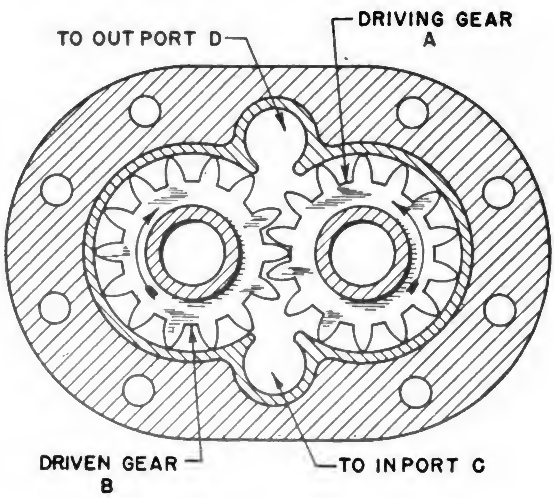


Figure 12. Gear type power pump.

in a housing. The clearance between the teeth as they mesh and between the teeth and the housing is very small. The inport *C* is connected to the reservoir, and outport *D* is connected to the pressure line. Gear *A* is attached to a drive shaft, which extends from the housing. Seals or cups are used to prevent leakage around the drive shaft. As gear *A* is turned counterclockwise by the drive shaft, it will turn gear *B* clockwise. As the teeth pass the edge of the inport, oil will be trapped between the teeth and housing. This oil is carried around the housing to the outport. As the teeth mesh, the oil between the teeth is displaced and forced out of port *D* into the pressure line.

c. Gerotor type pump. Figure 13 illustrates the gerotor type pump. This pump consists essentially of a housing containing a liner, an internal

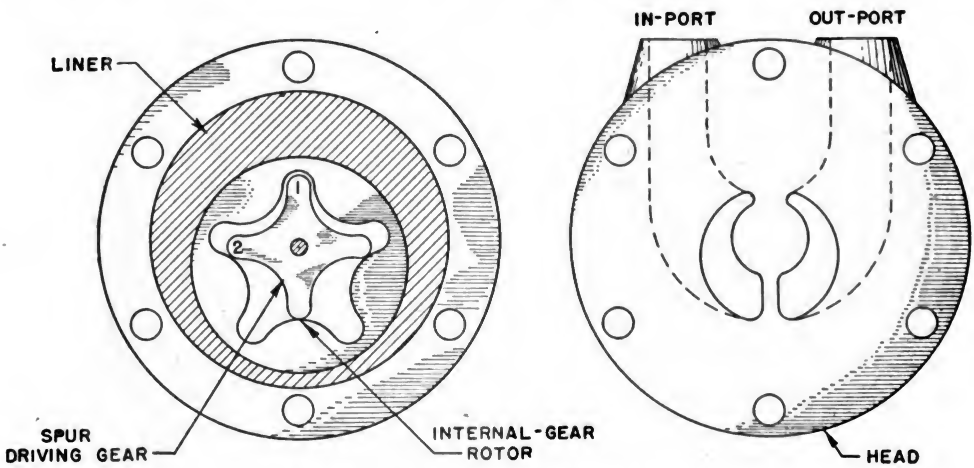


Figure 13. Gerotor type power pump.

gear rotor having five wide flat teeth, a spur driving gear having four narrow teeth, and the pump head, which contains two crescent-shaped openings. One opening is connected to the inport and the other opening is connected to the outport. The rotor is closely fitted in the liner. The drive gear, which is keyed to the drive shaft, is mounted off-center inside the internal gear rotor in such a way that one tooth is completely engaged with the internal gear. As the drive gear is turned, it will turn the rotor because the two gears are meshed. During one-half revolution (counterclockwise), the volume of the section between the rotor and the teeth labeled *1* and *2* will be increasing. Since this section is connected to the inport through the cresent-shaped openings in the head during this half revolution, oil will flow into the section. For the remaining one-half revolution, this section will be decreasing in volume. Since it is now connected to the outport through the other crescent-shaped opening in the head, oil will be forced out of the outport into the pressure line.

d. Vane type pump. The vane type pump is shown in figure 14. The unit consists essentially of a housing containing a steel sleeve with an eccentric (off center) bore, four blades or vanes, a hollow steel rotor, and

a coupling to turn the rotor. The blades are mounted in the rotor. The blades and the rotor divide the bore of the sleeve into four sections. Since the rotor is mounted off-center in the bore of the sleeve, the volumes of the sections will vary as the rotor is turned. As the rotor turns, each section will successively pass a point where its volume is at a minimum. From this point the volume is increasing for one-half revolution. During this time the section is ported to the inport *A* through a slot in the sleeve, and oil will flow into the section. During the remaining half of the revolution, the volume of the section is decreasing. During this time the section is ported to the outport *B* through a second slot in the sleeve. Since the oil is incompressible, it is forced out port *B* into the pressure line.

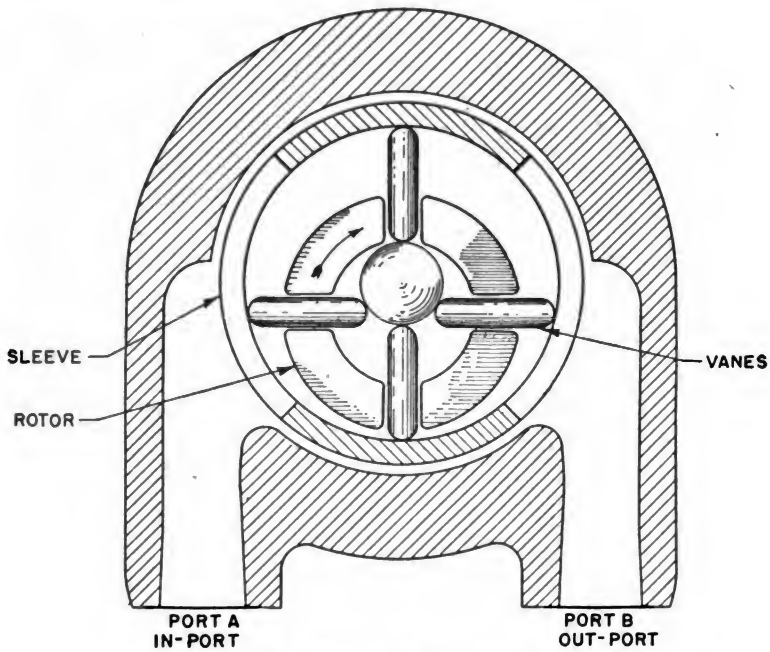


Figure 14. Vane type power pump.

e. Piston type power pump. (1) *Description.* The advantage of the piston type power pump is its ability to develop higher pressures than other types of pumps. This pump is of the positive displacement type. One version of this pump (fig. 15) consists of a housing, a cylinder barrel (containing seven cylinders), seven pistons and their connecting rods, a drive shaft to which the piston rods are attached by ball-and-socket joints, and the universal drive linkage. This cylinder-barrel housing is attached to the main housing at an angle. Mounted on the cylinder-barrel housing is a head which contains the inport *A* and the outport *B*. Located in the bottom of the main housing is a port which serves as a drain. A cup type seal prevents leakage of hydraulic oil around the drive shaft.

(2) *Operation.* As the drive shaft is rotated, it rotates the universal drive linkage which is essentially a rigid drive shaft with a flexible coupling on each end. This drive linkage rotates the cylinder barrel. During one-

half a revolution of the cylinder barrel, a given cylinder will be moving away from the face of the drive shaft. The piston is attached to the face of the drive shaft by its connecting rod, so that it must always remain the same distance from the drive shaft. As the cylinder moves away from the drive shaft, the piston will move toward the bottom of the cylinder. During this part of the cycle the cylinder is ported to the inport *A* through a passage in the head. Oil will therefore flow into the cylinder as the piston moves down. After the cylinder passes the bottom dead-center position, it is ported to the outport *B* by a passage in the head. During the remainder of the revolution the cylinder is moving closer to the face of the drive shaft. The piston therefore will move toward the top of the cylinder. The oil which filled the

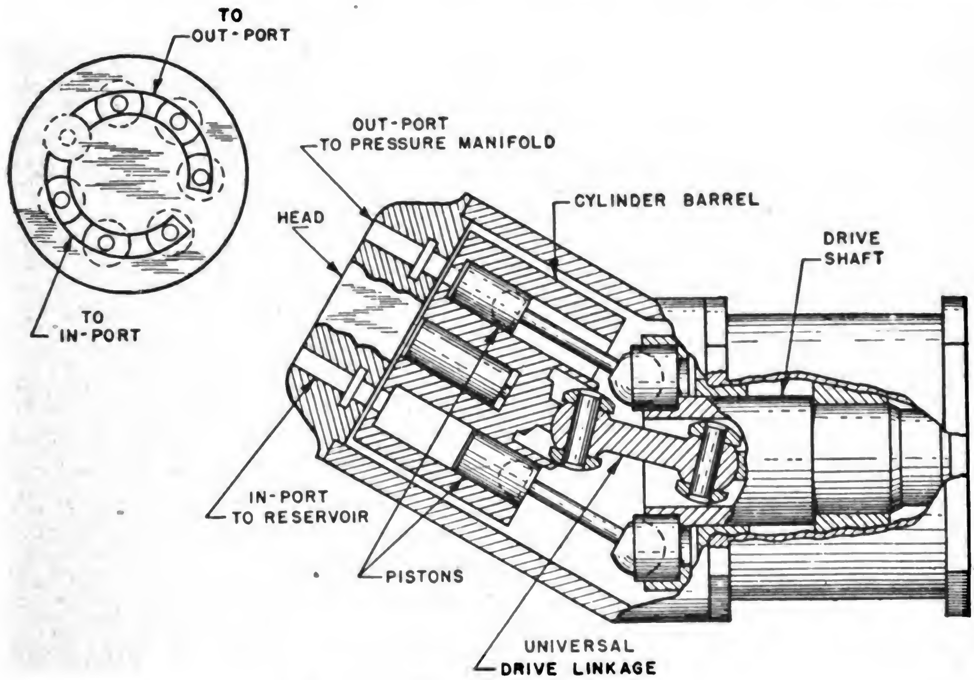


Figure 15. Piston type power pump.

cylinder during the first half of the cycle will now be forced out of port *B*. At all times three cylinders are connected to the inport, three cylinders are connected to the outport, and one cylinder is not connected to either port. As one cylinder ceases pumping, another cylinder begins. The flow of oil out of port *B* is therefore reduced to a minimum.

f. Inspection and maintenance. If a power pump is filled with oil for storage, a thorough cleaning will be necessary before installation. After washing the pump with a suitable solvent, flush it several times with the type of oil used in the system. At the first 50-hour inspection, the pump should be removed and the freedom of movement of the rotating parts should be checked by turning the drive shaft with the fingers. If excessive resistance to rotation is found, the pump should be replaced. Mounting bolts and tubing connections should be checked periodically. The pump should

be removed for overhaul at engine change. This applies even if a new pump has been installed between engine changes.

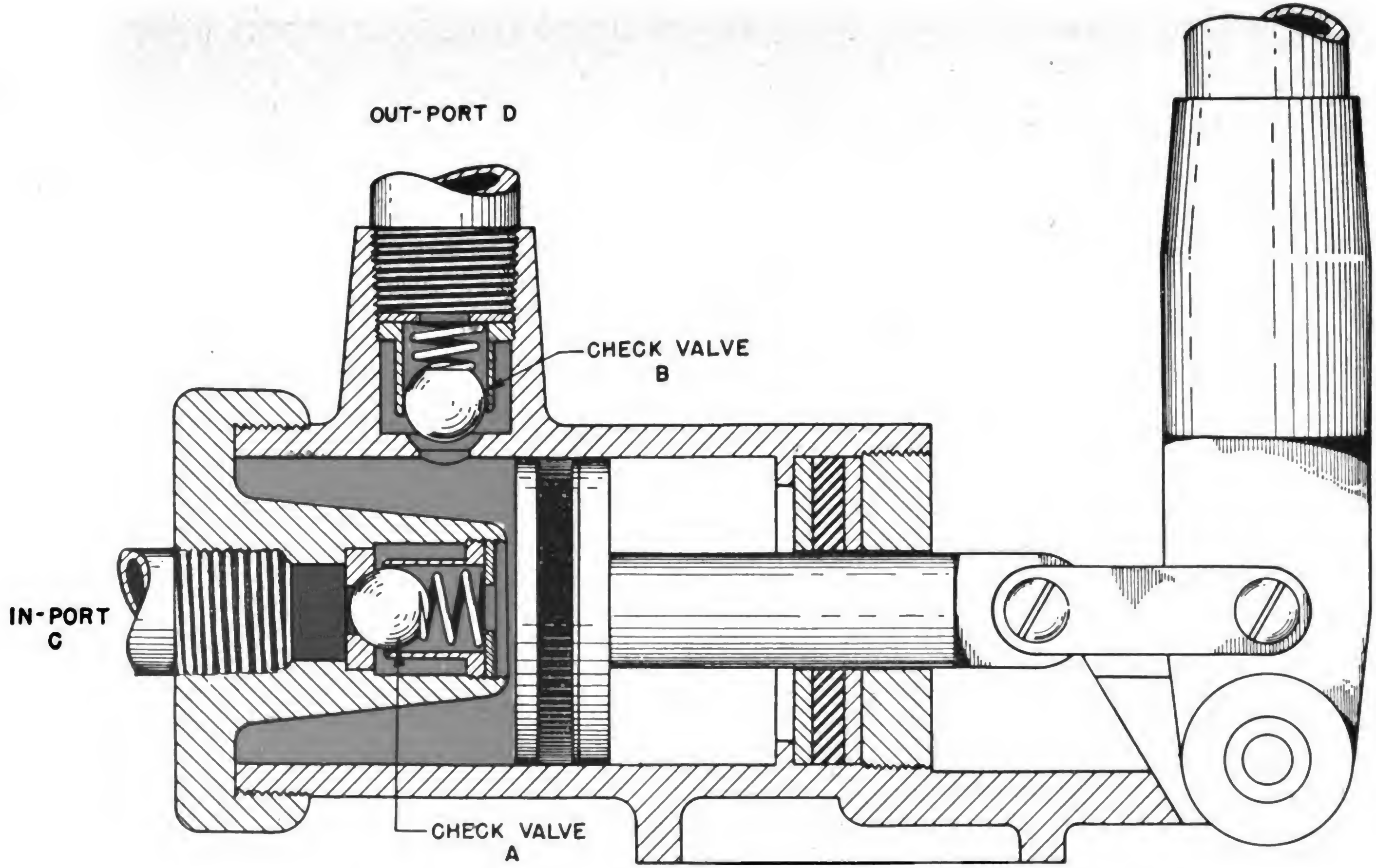
11. HAND PUMPS. a. Purpose and use. The purpose of the hand pump is to serve as a substitute for the power pump during emergencies in flight. It also serves as a source of pressure for ground-checking the hydraulic system when the airplane is at rest on the ground. All hand pumps are manually operated, reciprocating, piston type pumps. They may be classified as single-action and double-action pumps.

b. Single-action pump. Figure 16 shows the single-action pump. The unit consists of a cylinder, a piston, an operating handle, and two check valves *A* and *B*. The inport *C* is connected to the reservoir, and the outport *D* to the pressure manifold. As the piston is moved to the right by the operating handle, oil from the reservoir flows through the check valve *A* into the pump. As the piston is moved to the left, check valve *A* is closed and check valve *B* is opened. The oil in the pump is forced out of port *D* into the pressure line. Thus with each two strokes of the handle, a single pressure stroke is produced.

c. Double-action pumps. Pumps of the double-action type produce two pressure strokes for each two strokes of the operating handle. The double-action pump may be of the piston-rod displacement type or the piston displacement type.

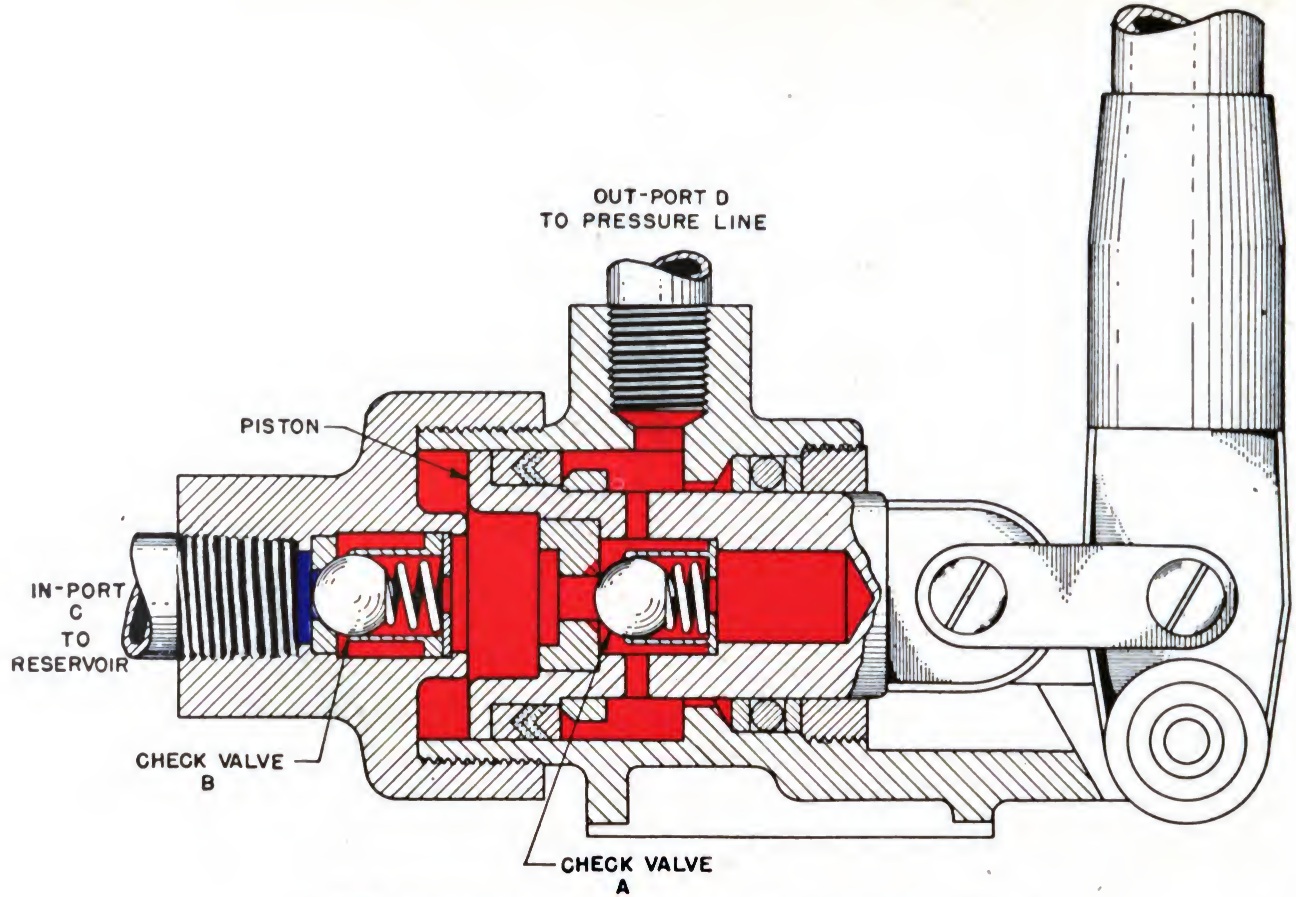
(1) *Piston-rod displacement type pump.* Figure 17 illustrates the piston-rod displacement type pump. This unit consists of a cylinder, a piston containing a built-in-check valve *A*, a large piston rod, an operating handle, and a check valve *B*. Some pumps of this type use a one-way seal on the piston instead of the internal check valve. As the piston is first moved toward the right, check valve *A* is closed and check valve *B* is opened. Oil from the reservoir will therefore flow into the pump. When the piston is moved toward the left, check valve *B* will be closed. Pressure created in the oil will open check valve *A* and oil will be admitted behind the piston. Because of the increasing volume of the piston rod entering the cylinder, there is room for only part of this oil. The remainder will be forced into the pressure lines. If the piston is again moved toward the right, check valve *A* is closed. The oil behind the piston is forced out of the outport *D*. At the same time oil from the reservoir flows into the cylinder through check valve *B*. Thus two pressure strokes are produced for each two strokes of the handle.

(2) *Piston displacement type hand pump.* Figure 18 represents the piston displacement type hand pump. The unit consists of a cylinder, a spool-shaped piston with two built-in check valves, *A* and *B*, an operating handle, and two other check valves, *C* and *D*. Oil flows from the reservoir to the middle of the spool-shaped piston. As the piston is moved toward the right, check valve *A* is closed and oil under pressure is forced out of check valve *D* into the system. At the same time check valve *C* is held closed by pressure, and oil from the reservoir flows through check valve *B* and fills



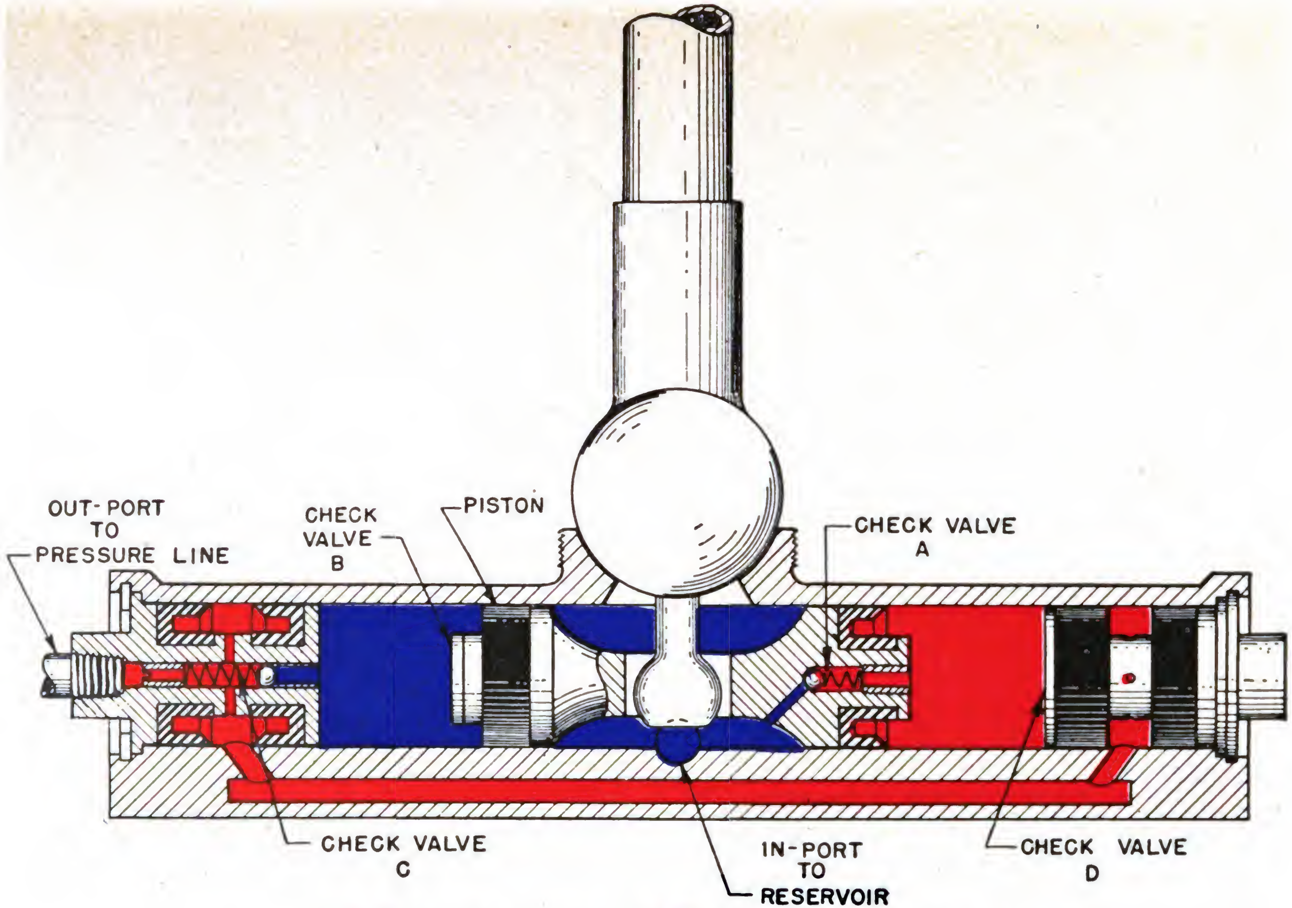
● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 16. Single-action hand pump.



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 17. Piston-rod displacement type hand pump.



● **Fluid under pressure.** ● **Fluid under atmospheric pressure.**

Figure 18. Piston displacement type hand pump.

the left end of the cylinder. When the piston is moved toward the left, check valve *B* is closed and oil is forced out of check valve *C* into the pressure line. At the same time check valve *D* is closed, and oil flows into the right end of the cylinder through check valve *A*. In this way, two pressure strokes are produced for each two strokes of the handle.

d. Inspection and maintenance. The hand pump is checked for condition and functioning periodically. Excessively easy operation is an indication of internal leakage. The hand pump is removed for overhaul at engine change if the unit has had more than 100 hours of service.

12. ACCUMULATORS. a. Purpose. The purpose of the accumulator is to store hydraulic oil under pressure. This oil can be used to supplement the power pump output during peak loads. It may also be used for limited operation of mechanisms when the power pump is not working. The accumulator also tends to dampen pressure surges in the hydraulic system.

b. Description. A pressure accumulator (fig. 19) consists of two hollow, hemispherical pieces of metal which may be screwed or bolted together.

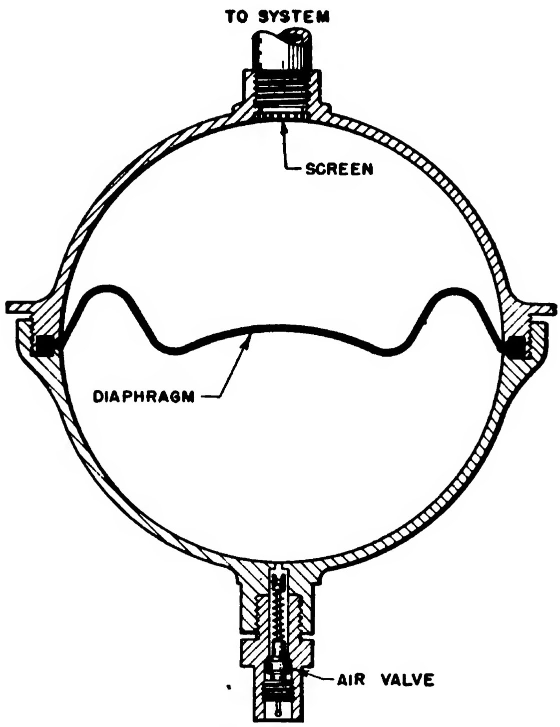


Figure 19. Pressure accumulator.

One of the halves has a fitting for attaching the unit to the system. The other half is equipped with an air valve for charging the unit with compressed air. Mounted between the two halves is a synthetic rubber diaphragm which divides the tank into two compartments. The unit is usually mounted with the air valve down. An initial charge of compressed air is put into the accumulator. This forces the diaphragm upward. When pres-

sure in the system builds up higher than the air pressure, oil will be forced into the top compartment. This oil will push the diaphragm down and further compress the air. During periods of peak load this highly compressed air will tend to force oil back into the system. If the power pump is not running, this air will supply a limited amount of oil under pressure for the operation of a mechanism.

c. Inspection and maintenance. Check visually for external oil leaks. Check for external air leaks with soapy water. Check for internal leaks by loosening the air-valve body. If oil comes out of the valve, the diaphragm or unit must be replaced. Disassembly and assembly of accumulators whose halves are bolted together is a depot function. Check the charge of air with a high-pressure gauge or as follows. With operating pressure in the system, operate the flaps slowly and watch the pressure gauge reading. The last reading before the needle suddenly drops to zero is the air pressure in the accumulator. When replacing the valve core, never use the standard tire type of core, as this would result in loss of air pressure and hydraulic system failure. The valve cores used in hydraulic accumulators are of a special high-pressure construction and use synthetic rubber or lead seals to resist the action of hydraulic fluid.

d. Removal and installation. (1) *Removal.* Before removing the unit, reduce the pressure in the system to zero by operating some mechanism. Then reduce the air pressure to zero by depressing the valve core or by partly unscrewing the valve core. Do not completely unscrew the valve core until the air pressure has reached zero. Disconnect the accumulator from the system and plug or cap the fitting.

(2) *Installation.* Before installing a new unit, charge it with the required air pressure. Remove the plug or cap and connect the unit to the fitting on the pressure line. The oil level in the reservoir should be checked after the unit is installed.

13. HYDRAULIC GENERATORS AND MOTORS. a. Purpose. The purpose of a hydraulic generator is to produce the comparatively low pressures needed to drive a hydraulic motor. The purpose of the hydraulic motor is to transform pressure into torque (twisting) force to operate some mechanism.

b. Hydraulic generators. Essentially the hydraulic generator is a power pump. The only difference between a generator and a pump is that the generator is designed to develop lower pressure than the pump. The discussion of power pumps in a previous paragraph applies also to the hydraulic generator.

c. Hydraulic motors. The hydraulic motor is an actuating unit used instead of the conventional actuating cylinder because of scarcity of space or need for rotary motion. For the standpoint of construction a hydraulic motor is the same as a power pump. Its operation, however, is directly opposite. The drive shaft of the motor is connected to the mechanism to

be driven. One port in the motor housing is connected to the return line. Oil under pressure enters the other port and drives the pump and the mechanism attached to the drive shaft. Gear, vane, and piston type motors are used. Fuel pumps, gun turrets, and wing flaps are among the mechanisms operated by hydraulic motors.

d. Inspection and maintenance. The instructions for the inspection and maintenance of power pumps in paragraph 10 are applicable also to hydraulic generators and motors.

14. ACTUATING CYLINDERS. a. Purpose. The purpose of actuating cylinders is to transform pressure into mechanical force or action. They are used where linear motion is required to move some mechanism.

b. Description. These units consist essentially of a cylinder, one or more pistons and piston rods, and the necessary seals. Actuating cylinders are usually double-acting. That is, oil under pressure can be applied to either side of the piston to provide movement in either direction. Single-acting cylinders with a spring return are sometimes used to actuate brakes, to charge guns, etc.

(1) *Single-port actuating cylinder.* Figure 20 illustrates the single-port actuating cylinder. Oil under pressure enters port *A* and moves the piston toward the opposite end of the cylinder against the force of the spring.

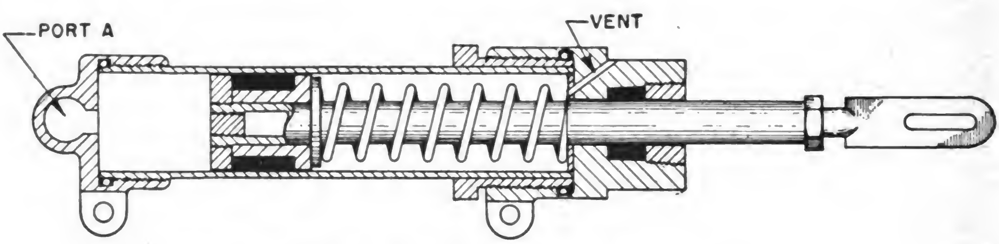


Figure 20. Single-port actuating cylinder.

When the operation has been completed and the pressure is released, the spring returns the piston to its original position.

(2) *Two-port actuating cylinder.* Figure 21 shows the most commonly used type of two-port actuating cylinder. Oil under pressure entering port *A* will force the piston to the opposite end of the cylinder, and the mechanism

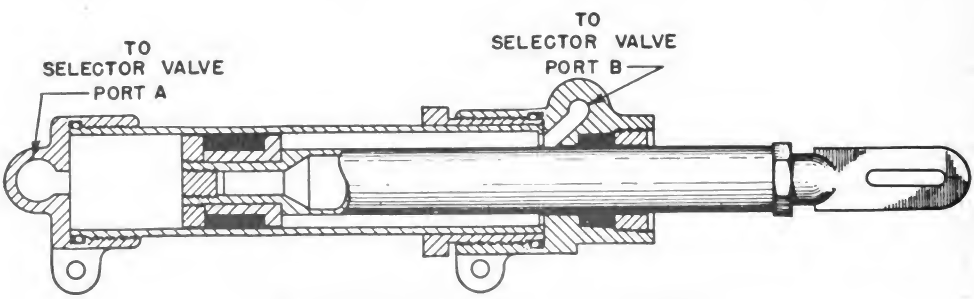


Figure 21. Two-port actuating cylinder.

attached to the rod will be moved. At the same time, the oil ahead of the piston is forced out of port *B* and returned to the reservoir. If oil under pressure is directed into port *B*, the direction of movement of the piston and the mechanism is reversed. Oil ahead of the piston is now forced out of port *A* and returned to the reservoir. With this type of actuating cylinder, a mechanism can be moved in either direction by changing the direction of flow of the oil.

(3) *Three-port actuating cylinder.* Figure 22 shows a three-port actuating cylinder that has two pistons. Oil under pressure entering port *A* will move both pistons outward, and the mechanisms attached to the piston rods

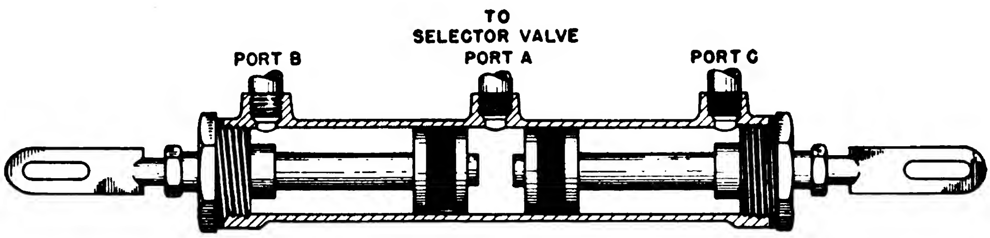


Figure 22. Three-port actuating cylinder.

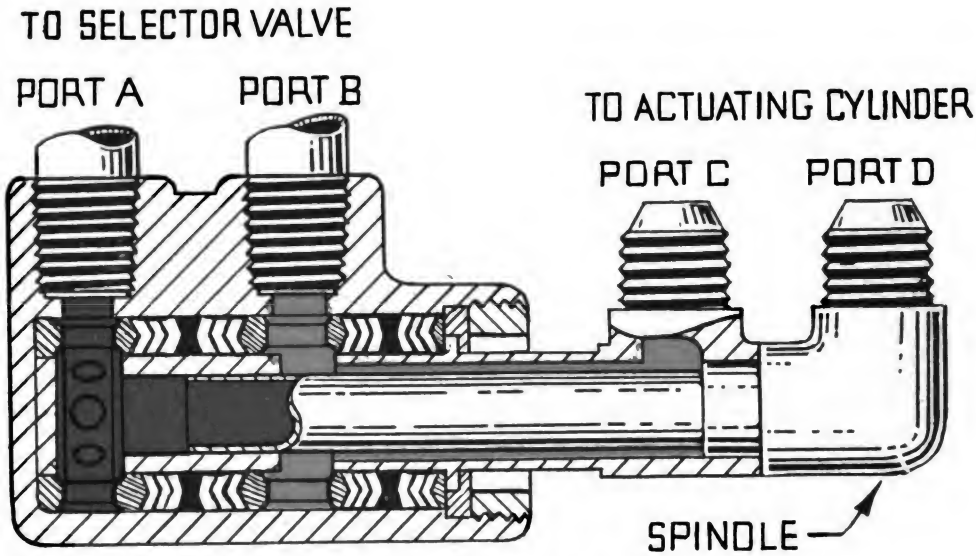
will be moved. Oil ahead of the pistons will be forced out ports *B* and *D* and returned to the reservoir. If oil under pressure is directed into ports *B* and *C*, the pistons will be moved inward and the mechanisms will be moved in the opposite directions.

c. Maintenance. The unit should be inspected for external leakage. If leakage around the end caps is discovered, tighten the cap. If this fails to stop leakage, replace the gasket. If the unit leaks around the piston rod, tighten the packing retainer nut. If this does not stop leakage, replace the packing. If the piston packing must be replaced, protect it by placing shim stock in the end of the cylinder before replacing the piston.

15. SWIVEL JOINTS. a. The purpose of swivel joints is to allow the use of rigid tubing in the plumbing of a hydraulic unit which rotates about a fixed pivot point. For instance, if the landing-gear actuating cylinder has to rotate during the raising and lowering of the gear, a swivel joint will be incorporated in the system. The use of a swivel joint eliminates the use of flexible tubing. One type of swivel joint is designed for fixed mounting and another type for floating mounting. The operation of these units is essentially the same.

b. Description. The unit shown in figure 23 consists of a housing, a spindle, and a packing group which seals but permits rotation between the spindle and housing. The housing is provided with two ports *A* and *B* for connection to the selector valve lines. One end of the housing is threaded to receive the packing retainer cap. When screwed into the housing, this cap pushes against a washer. This washer pushes against a shoulder on the spindle and holds the spindle in the housing. The spindle also has two ports

C and *D* each of which is connected to one of the ports in the housing through passages inside the spindle.



● ***Fluid under pressure.*** ● ***Fluid under atmospheric pressure.***

Figure 23. Swivel joint.

c. Operation. Oil under pressure from the selector valve enters port *B* and is directed between the inner and outer part of the spindle to port *C*. From this port oil is directed through tubing to the actuating cylinder. Oil from the actuating cylinder enters port *D*, goes through the hollow inner part of the spindle, and is directed out port *A* to the return line. The packing group in the housing prevents leakage between ports *A* and *B* and between the passages in the spindle.

d. Inspection and maintenance. Before installation the unit should be thoroughly flushed with the hydraulic fluid with which the unit was designed to operate. *No other* type of oil should be used. If external leakage around the spindle is found, replace the packing. Internal leakage is indicated by sluggish operation of the mechanism served by the joint. If this condition is found, replace the packing.

SECTION III

PUMP UNLOADING VALVES

16. GENERAL. a. Hydraulic power pumps which are used on aircraft are not designed to run continuously under full load. If a pump is engine-driven, an unloading valve must be included in the system. This unit unloads the power pump by bypassing the fluid directly from the pressure manifold to the return manifold.

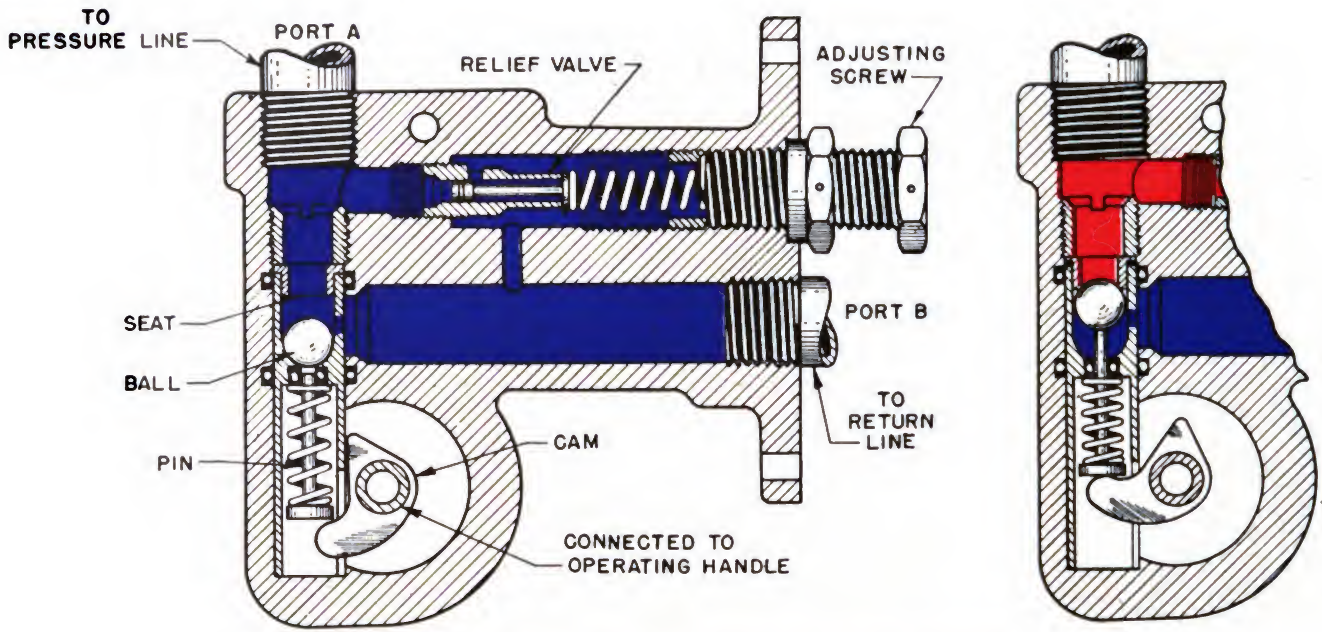
b. Some pump unloading valves are operated manually. However, most of them are semiautomatic or completely automatic.

17. PUMP-CONTROL VALVE. a. Purpose. The purpose of pump-control valves is to allow the pilot to direct (manually) the output of the pump to the main hydraulic system when some mechanism is to be operated, or to the reservoir when there is no need for pressure.

b. Description. The pump-control valve has two external ports. In the pressure port *A* (fig. 24) is a ball which can be held off its seat by fluid flowing through the unit to the return line. Below the ball is a cam-and-pin assembly by means of which the ball can be forced onto its seat. An integral relief valve is installed between the pressure and return ports.

c. Operation. When no mechanism is being operated, fluid from the power pump will enter port *A* and flow out of port *B*. This open position of the unit is shown in figure 24①. If some mechanism is to be operated, the control handle is moved to the closed position. This action rotates the cam, the cam pushes the pin up, and the pin forces the ball onto its seat and holds it there. This position is shown in figure 24②. As fluid can no longer reach the return line, it will be directed to the control units. After the mechanism reaches the end of its travel, pressure will build up rapidly. When the pressure reaches the "kick-out" pressure of the relief valve. this valve will open and the output of the power pump will be directed to the return line. When the control handle is placed in the open position, the ball and pin will return to the position shown in figure 24① and the output of the pump will be directed to the return line again.

d. Adjustment. Adjustment of the relief valve is accomplished by means of the external adjusting screw. Clockwise turning increases the "kick-out" pressure, and counterclockwise turning reduces the "kick-out" pressure.

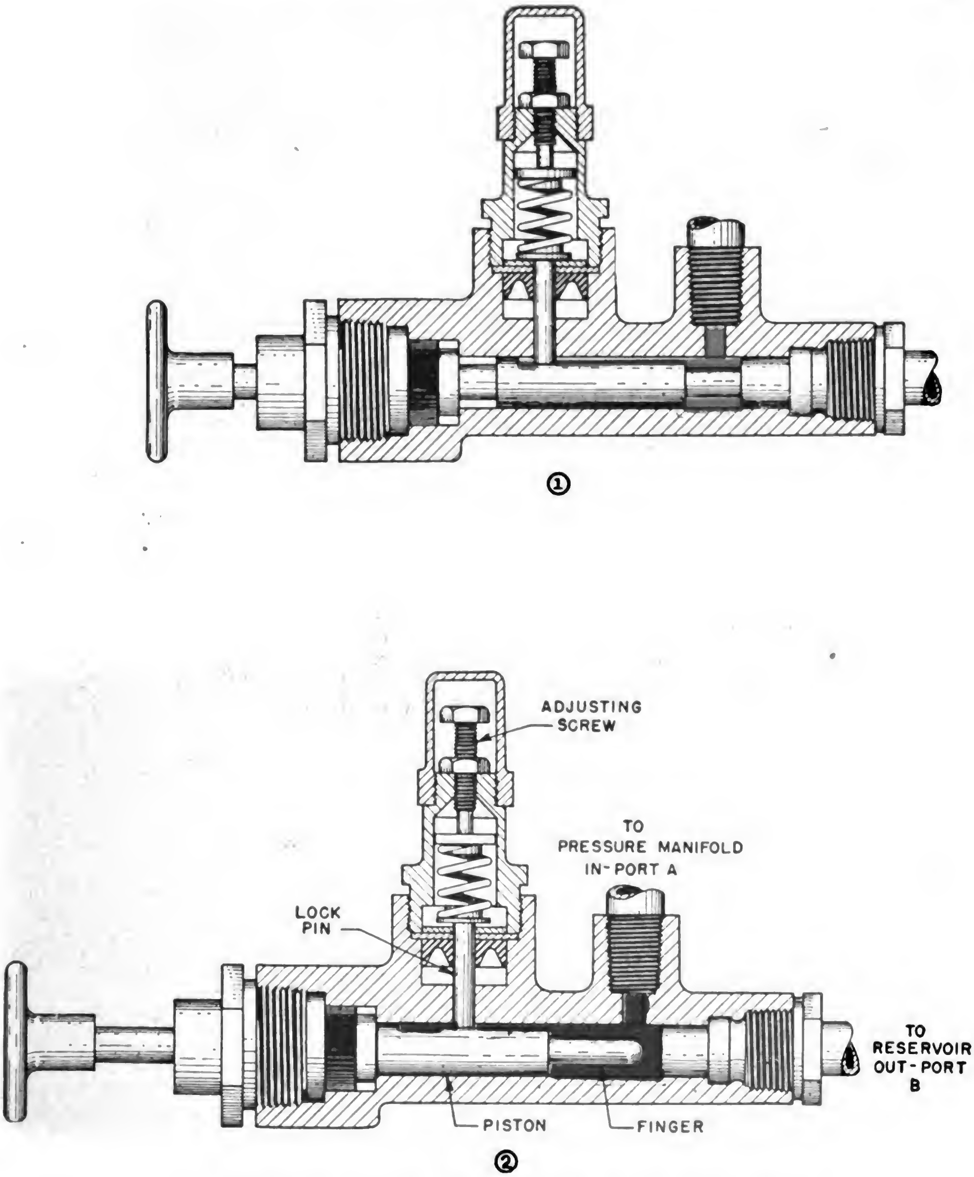


● ***Fluid under pressure.*** ● ***Fluid under atmospheric pressure.***

Figure 24. Pump-control valve.

18. POWER-CONTROL VALVE. a. Purpose. Essentially a power-control valve is a hand shut-off valve with an automatic turn-on feature. It is semiautomatic in operation; that is, it must be closed manually but opens automatically. When the unit is open, it permits free circulation of oil from the power pump to the reservoir and thus relieves the pump of load.

b. Description. Figure 25 shows a drawing of the power-control valve. The housing has an inport *A* and an outport *B*. A plunger extends from one end of the housing. This plunger is not attached to the piston. Inside the housing is a piston and a spring loaded lock pin. On one end of the piston is a projecting "finger" which closes port *B* when the plunger



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 25. Power-control valve.

is pushed in. The piston also has a notch which engages the lock pin when the plunger is pushed in.

c. Operation. (1) When it is desired to operate some mechanism, the plunger is pushed in. This moves the piston toward the right and the finger on the end of the piston closes port *B* and stops the flow of oil to the reservoir. At the same time the notch in the piston moves opposite the lock pin. This pin is held in the notch by the spring, and the piston is locked in the position shown in figure 25①. The output of the power pump will now be directed to the mechanism being operated. When the mechanism reaches the end of its stroke, pressure will immediately increase. This pressure will act on the end of the piston and on the end of the lock pin. When pressure acting on the end of the lock pin becomes great enough to overcome the force of the lock-pin spring, the lock pin will be forced out of the notch. Thus the piston will be released and pressure will move it to the left and open the return port. Oil can then flow freely from the power pump to the reservoir as shown in figure 25②.

(2) Some power-control valves have a check valve built into the housing opposite the inport. In this type of unit, oil from the power pump flows through the unit and out of the check valve to the system when the unit is closed. When the unit is open, oil flows through the unit and out of the return port. The built-in check valve closes and traps pressure in the system when the return port is opened.

d. Inspection and maintenance. Seals and gaskets may be replaced in case leakage is found. A visual inspection will usually indicate the faulty seal. Do not disassemble the unit any more than necessary to replace a faulty seal or gasket.

19. TIME-LAG POWER CONTROL VALVE. a. Purpose. The purpose of the time-lag control valve is to relieve the power pump of load when no mechanism is being operated.

b. Description. A drawing of a typical time-lag valve is shown in figure 26. The unit consists essentially of a three-port housing containing a plunger and a metering valve. One end of the plunger extends outside the housing. This plunger is mounted in line with the return port *B*. A piston head is mounted on the plunger. This head is equipped with a one-way cup which will allow oil to flow by the head toward the left only. The metering valve is installed in such a way that oil passing through it is bypassed around the one-way cup on the piston head.

c. Operation. (1) When the unit is open, oil from the power pump comes in port *A* and goes to the return line through port *B* because of the lower pressure in the return line. This position of the unit is shown in figure 26①.

(2) When it is desired to operate some mechanism, the plunger is pushed inward and the end of the plunger closes port *B*. This directs the output of the power pump to the selector valve as shown in figure 26②. As the piston

moves inward, oil goes by the one-way packing cup and keeps the space behind the piston head full of oil. This oil cannot come back by the cup, so it must be forced through the metering valve before the plunger can return to the open position. Since the pressure on both sides of the piston head is the same, a force must be supplied to move the plunger to the open position. This force is furnished by the spring between the piston head and the housing. The size of the opening around the metering pin determines the speed with which the plunger will move. An external adjusting screw is provided to adjust the size of this opening.

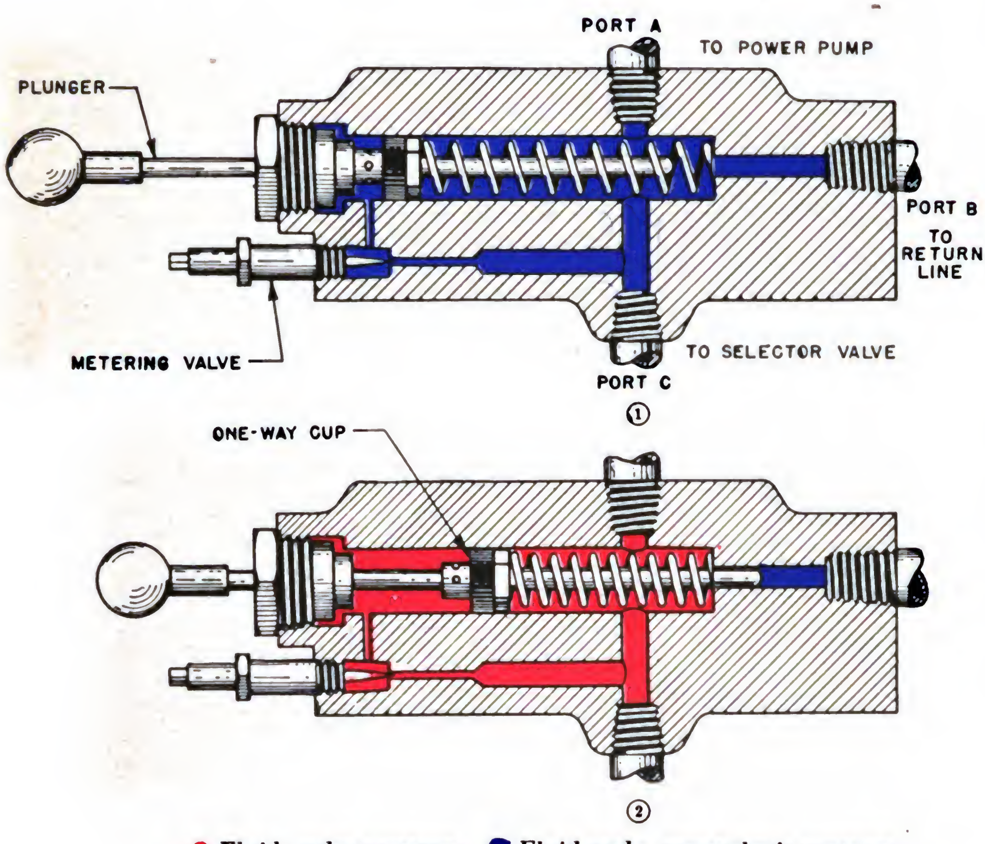


Figure 26. Time-lag power control valve.

d. Inspection and maintenance. The operation of this unit should be inspected, and the time it stays engaged, or closed, should be at least twice that required for any operation of the landing gear or flaps. Screwing in the adjusting screw increases the time the unit remains *closed*, and unscrewing decreases this time. If the unit cannot be adjusted to remain engaged long enough, check the one-way cup. Replace the cup if necessary. Operation of this unit should never be checked when the system is cold. Operate the power pump long enough for the fluid to become warm before checking.

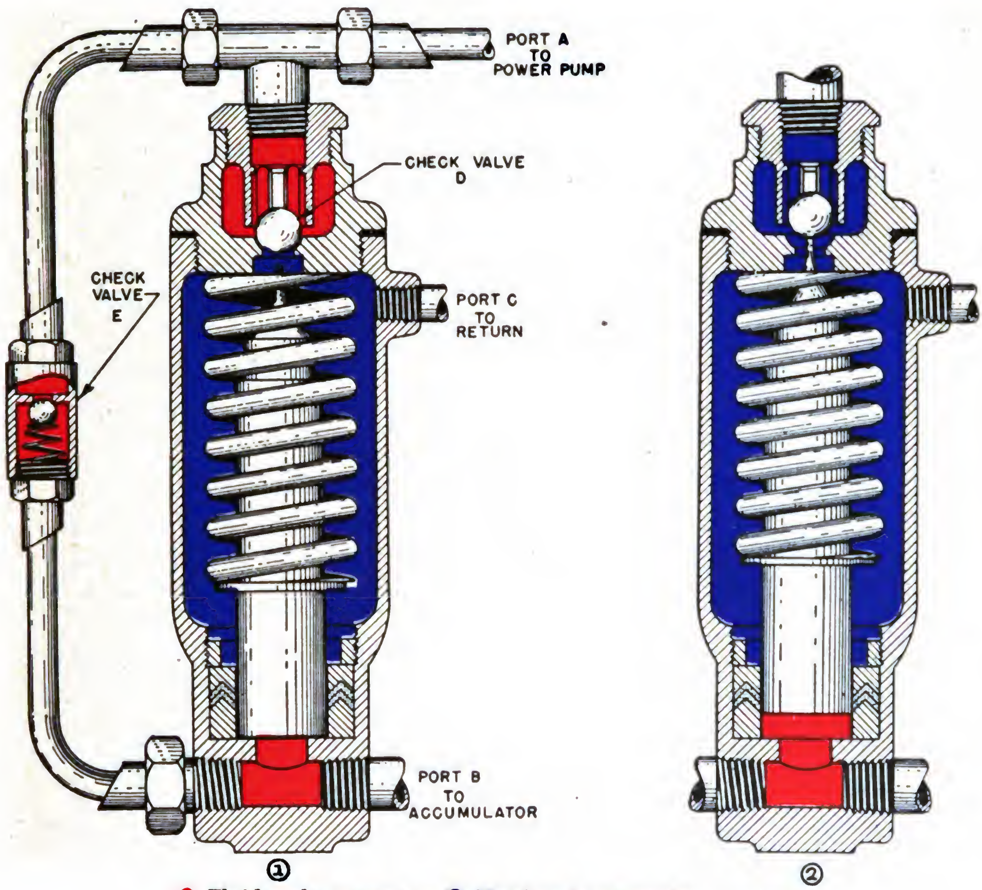
20. PRESSURE REGULATORS. a. Purpose. (1) The pressure regulator is completely automatic in operation. The principal purpose of the unit is to relieve the pump of load. When pressure in the system reaches a certain maximum, the unit opens and allows the output of the power pump to return to the reservoir. If system pressure drops to a certain minimum, the unit closes and directs the output of the power pump to the system.

(2) Many different types of pressure regulators are used on modern airplanes. Although these units may differ in construction and appearance, they all serve the same purpose in the system. Regulators may be classified under three broad headings: balanced type, mechanical type, and spool type. One example of each of these types will be discussed.

b. Balanced type. (1) *Description.* Figure 27 illustrates the balanced type of regulator. It consists of a housing having three ports *A*, *B*, and *C*, a spring-loaded piston to which a pin is attached, and two ball type check valves *D* and *E*. Check valve *E* is located in a bypass line between ports *A* and *B*.

(2) *Operation.* When the unit is in the position shown in figure 27①, the check valve *D* is seated, the piston is held down by the spring, and oil from the power pump flows to the system through the external line and check valve *E*. Pressure holds check valve *D* on its seat. This same pressure is transmitted through port *B* and acts on the bottom of the piston. This produces a force which tends to move the piston up and open check valve *D*. Let a set of imaginary valves be assumed to show how the unit operates. Suppose the spring has a force of 600 pounds, the ball seat an area of $\frac{1}{3}$ square inch and the piston an area of 1 square inch. If the pressure in the system is 600 pounds per square inch, the force holding the ball down will be 200 pounds. This force plus the 600-pound force of the spring will give a total force of 800 pounds acting downward. System pressure acting on the piston produces a force of 600 pounds, acting upward. The resultant of these two forces will be a force of 200 pounds acting downward. The check valve *D* will therefore remain closed. If system pressure increases to 750 pounds per square inch, the force holding the ball down increases to 250 pounds. The force of the spring remains 600 pounds, so that the total downward force is 850 pounds. The upward force on the bottom of the piston is now 750 pounds. The resultant of these two forces is a force of 100 pounds acting downward, so that check valve *D* will still remain closed. If system pressure increases to 900 pounds per square inch, the force holding the ball down increases to 300 pounds. This force plus the 600-pound force of the spring gives a total force of 900 pounds acting downward. The upward force on the piston has increased to 900 pounds; hence the two forces balance each other and the check valve *D* will remain closed. If system pressure increases above this point—say, to 903 pounds per square inch—the force holding the ball down increases to 301 pounds. This plus the force of the spring gives a total downward force of 901 pounds. The upward force on the piston has increased to 903 pounds. The resultant of these

forces is a force of 2 pounds upward. As a result, the piston will move up and the pin will open check valve *D*. Oil from the pump is then free to flow through check valve *D*, out of port *C*, and to the reservoir. This position of the unit is shown in figure 27②. When check valve *D* opens, check valve *E* closes and traps pressure on the bottom of the piston and in the system. This pressure will keep the regulator open and allow the pump to operate without load. Since check valve *D* is now off its seat, the force of the spring is the only force tending to move the piston down. System pressure acting on the bottom of the piston tends to hold the piston up. The regulator will therefore remain open until system pressure drops below the value necessary to overcome the force of the spring. When this occurs, the spring will move the piston down, check valve *D* will seat, and the output of the pump will again be directed to the system.

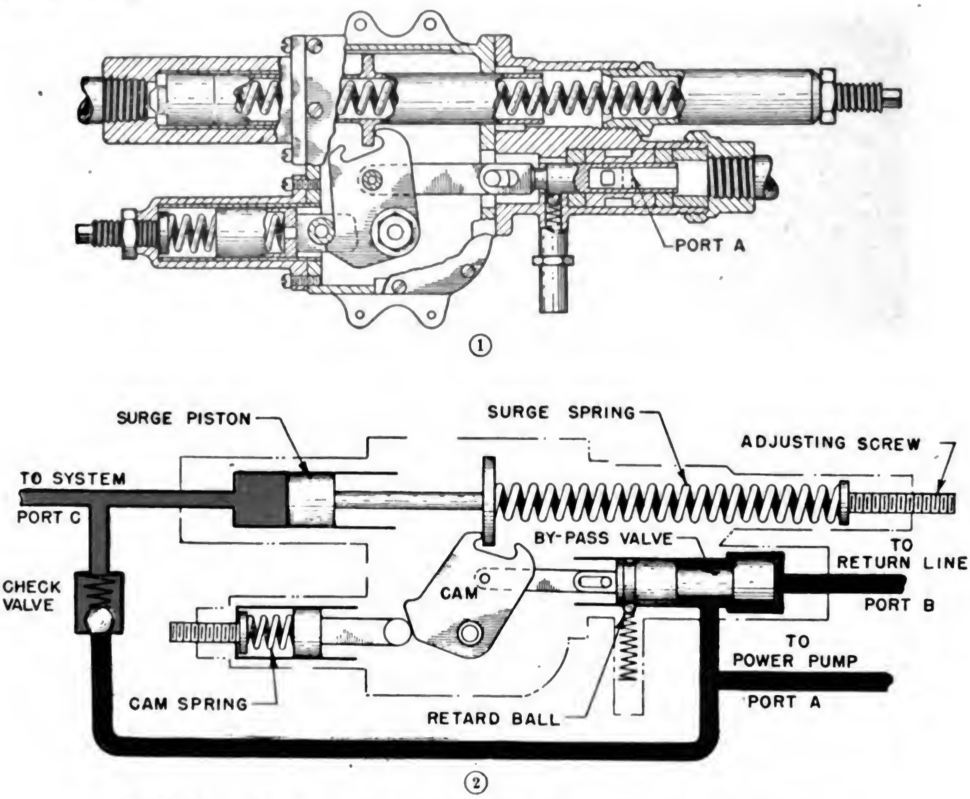


● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 27. Balanced-type pressure regulator.

c. Mechanical type. (1) *Purpose.* Figure 28 is a drawing of the mechanical type regulator. This unit is used without a pressure tank or accumulator. The path of the oil is determined by the position of a bypass valve. This valve is moved mechanically by a cam arrangement inside the unit.

(2) *Description.* There are three external ports in the housing of this unit. Port *A* (fig. 28) is connected to the power pump, port *B* to the return line, and port *C* to the main pressure line of the system. Attached to the housing are the surge barrel (containing the surge piston and surge spring), the bypass valve housing (containing the bypass valve), and the cam-plunger housing (containing the cam spring and plunger). Inside the main housing are a cam and the bypass valve connecting linkage. This linkage is provided with a link-and-pin connection which permits delayed response of the bypass valve cam movement. Units designed for use in systems which incorporate an automatic pilot have two drain openings in the bottom of the housing.



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 28. Mechanical type pressure regulator.

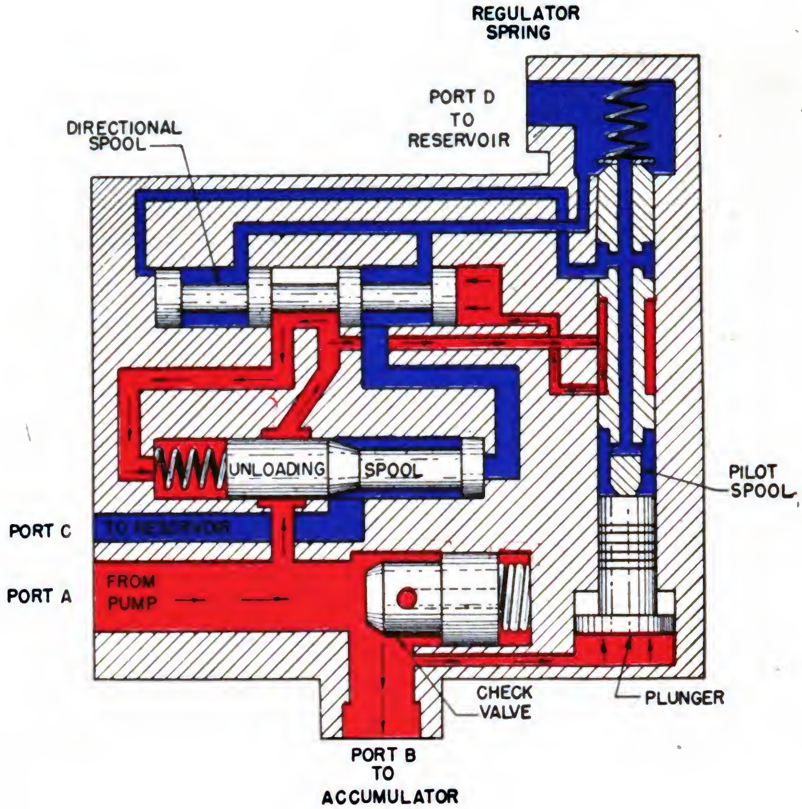
(3) *Operation.* Oil entering port *A* is directed through the external line and check valve (fig. 28②) to the surge chamber and to the system through port *C*. Pressure developed in the system acts on the face of the surge piston. This pressure tends to move the surge piston toward the right against the force of the surge spring. On the rod attached to the surge piston is a flange which engages the cam. This cam is connected to the bypass valve by the bypass valve connecting linkage. Movement of the surge piston toward the right will therefore rotate the cam about its pivot in a clockwise direction and tend to open the bypass valve. On the bottom of the cam is a lobe. As the cam rotates, a roller on the cam plunger will ride up one side of the

lobe, over the high point, and down the other side. As the roller rides up the lobe, the cam plunger is forced toward the left against the force of the cam spring. The cam spring and the surge spring *both* oppose the clockwise rotation of the cam. When system pressure builds up enough to overcome the force of the *two* springs, the surge piston will be forced toward the right, the cam will be rotated about its pivot, and the bypass valve will be opened. Oil will then flow around the bypass valve and out port *B*, and the pump will be relieved of load. This position of the unit is shown in figure 28②. Pressure will be trapped on the surge piston and in the system by the check valve. If this pressure is reduced by leakage or by a change in the setting of a selector valve, the surge spring will tend to force the top of the cam toward the left. (A small amount of leakage will not open the bypass valve, because of the lost motion in the bypass valve connecting linkage. A spring loaded "retard ball" holds the bypass valve in the open position until the cam moves enough to take up the lost motion.) As the cam rotates counterclockwise, the roller on the cam plunger will again ride up the lobe and compress the cam spring. For this movement of the cam, the surge spring is opposed by the cam spring and system pressure. When system pressure drops enough to allow the surge spring to overcome the cam spring, the top of the cam will move toward the left and close the bypass valve. When the unit is "kicking out," the surge spring is *aided* by the cam spring. When the unit is "kicking in," the surge spring is opposed by the cam spring. This accounts for the difference between "kick-in" and "kick-out" pressure.

d. Spool type. (1) *Purpose.* Figure 29 shows the spool type regulator. This type is used with one or more pressure tanks or accumulators. The path of the oil is determined by the position of an unloading spool. An internal check valve prevents loss of accumulator pressure when the unit is "kicked out."

(2) *Description.* There are four external ports in the housing of this unit. Port *A* (fig. 29) is connected to the power pump, port *B* is connected to the pressure manifold, and ports *C* and *D* are connected to return. Port *D* serves as an external drain. This port is found only on some models. Models which do not have this port utilize an internal drain which opens into port *C*. Inside the housing are three spools. The positions of these spools determine the direction of flow of oil through the drilled passages in the unit.

(3) *Operation.* (*a*) With the unit in the position shown in figure 29①, the unit is "kicked in," and oil from the power pump is directed through the open check valve to the accumulator. As pressure builds up, it will act in the direction shown by the arrows. As long as the pilot spool is held down by the regulator spring, pressure will travel around the unloading spool and be directed against the right end of the directional spool. This pressure will hold the directional spool toward the left. As long as the directional spool remains in this position, pressure is directed against the left end of the unloading spool. This holds the unloading spool toward



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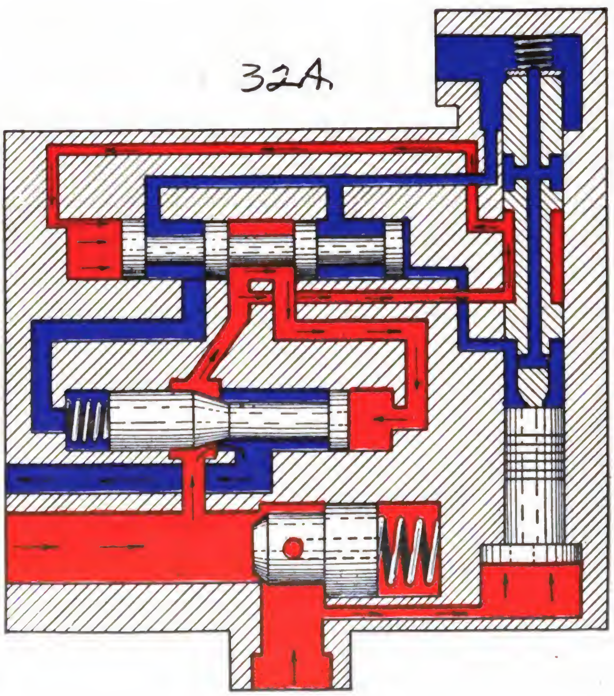
32A



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● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 29. Spool type pressure regulator.

the right and prevents oil from the power pump from reaching port *C*. When system pressure becomes great enough to overcome the force of the regulator spring, the pilot spool will be forced up, as shown in figure 29②.

(*b*) Shoulders on this spool will then direct pressure to the passage leading to the left end of the directional spool and connect the right end of this spool to the return port through the hollow pilot spool. Pressure will then move the directional spool to the right. Shoulders on the directional spool will then direct pressure through internal passages to the right end of the unloading spool and connect the left end of the unloading spool to the return. This spool will be moved to the left, so that ports *A* and *C* are connected. The output of the pump will then be directed to the reservoir, and the pump will be unloaded. The unit is now "kicked out." The check valve will close and trap pressure in the system and on the end of the pilot spool. The unit will remain in this position until the pressure in the system is reduced. If some mechanism is operated, the pressure holding the pilot spool up will decrease, and the regulator spring will force the pilot spool down. The directional spool and the unloading spool will again be moved to the position shown in figure 29①, and the "kick out" operation will be repeated.

e. Inspection and maintenance. Pressure regulators should be regularly checked for proper operation, leakage, and security of mounting.

(1) The mechanical type regulator should not require adjusting unless the unit is disassembled. To raise the operating pressure of the unit, tighten the external adjusting screw on the end of the surge barrel. If the operation of the regulator is sluggish, tighten the external adjusting screw on the end of the cam-plunger housing until the action of the regulator is sufficiently brisk. This screw is used also to adjust the "kick in" pressure. If the unit has drain openings in the housing, it should be mounted with the drain openings on the bottom. If the regulator "kicks in" and "kicks out" continually, inspect the check valve. If the check valve is not faulty, a leaky packing on the surge piston is indicated.

NOTE. The surge spring is installed with considerable preloading. Removal of the surge piston should not be attempted without an arbor press or drill press.

(2) The operating pressure of the spool type regulator can be changed only by replacing the regulator spring. Unscrewing the cap on top of the unit allows access to this spring. The cap should always be pulled down snugly. If the regulator will not charge the accumulator, the regulator spring may be broken, or the unloading or directional spool may be stuck in the open position. Inspect the spring. If it is not broken, remove the spools and inspect them. If they are not damaged, wash them thoroughly and replace them. A very small particle of foreign matter will cause these spools to stick; extreme care should therefore be exercised when reassembling. If the valve "chatters" or will not maintain pressure in the accumulator (when there is no leakage in the rest of the system), inspect the internal

check valve. If the check valve seats properly, check for leakage past the plunger.

(3) The operating pressure of the balance type regulator cannot be adjusted unless an arbor press is available. When the unit is assembled, the spring is under considerable load. If the unit is not held in a press when the cap is unscrewed, there is danger that the unit may be harmed or personnel injured.

SECTION IV

FLOW CONTROL VALVES

21. GENERAL. The purpose of flow-control valves is to control the direction or rate of flow of oil through the hydraulic system.

22. ORIFICES AND VARIABLE RESTRICTORS. a. Purpose. The purpose of an orifice or a variable restrictor is to limit the rate of flow of oil in both directions in a line. In so doing, these units cause the mechanism being operated to move more slowly.

b. Description. An orifice and a variable restrictor differ only in construction. The size of an orifice is usually fixed, whereas the size of the opening in a variable restrictor can be changed.

(1) An orifice is shown in figure 30. It is essentially a fitting containing a small passage. Oil entering one end of the fitting must pass through the small passage before flowing out the opposite end.

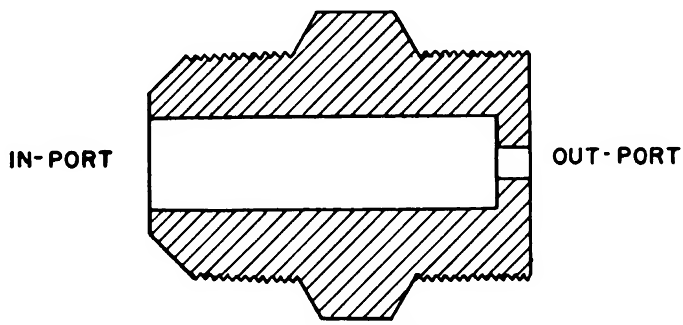


Figure 30. Orifice.

(2) The housing of a variable restrictor (fig. 31) has two ports and an adjustable needle valve. The size of the passage through which the oil must pass may be adjusted by screwing the needle valve in or out.

23. CHECK VALVE. a. Purpose. The purpose of check valves is to allow free flow in one direction and no flow in the opposite direction. They may be used to trap pressure in some part of the system. Check valves may be used in the pressure or return manifold.

b. Description. A typical check valve is shown in figure 32. The checking device may be a ball, a cone, or a button. This device is ground

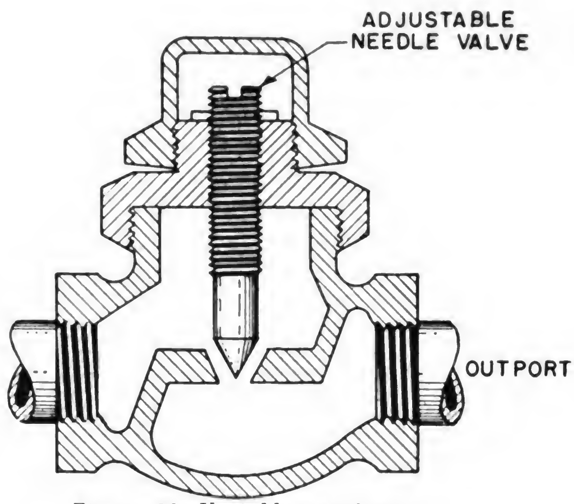


Figure 31. Variable restrictor.

to fit the seat perfectly to prevent leakage. A light spring holds the checking device on its seat. Oil entering port *A* will unseat the ball and flow out port *B*. When the flow of oil ceases, the spring returns the ball to its seat and thus traps the oil which has passed through the unit. The direction of free flow through the unit is indicated by an arrow stamped on the housing. Double ball type check valves contain two balls instead of one.

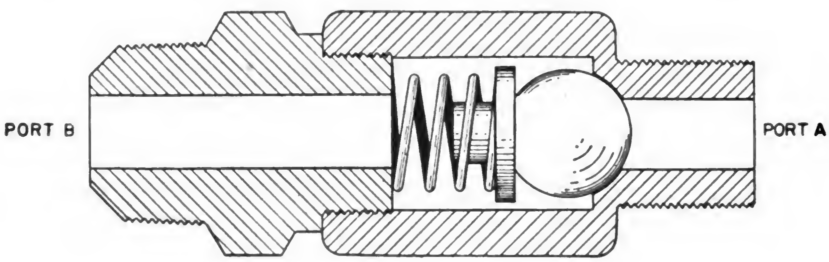


Figure 32. Check valve.

24. ORIFICE CHECK VALVE. a. Purpose. The function of the orifice check valve is to allow free flow in one direction and restrained flow in the other direction. This unit is used to retard the operation of flaps, landing gear, etc., in one direction.

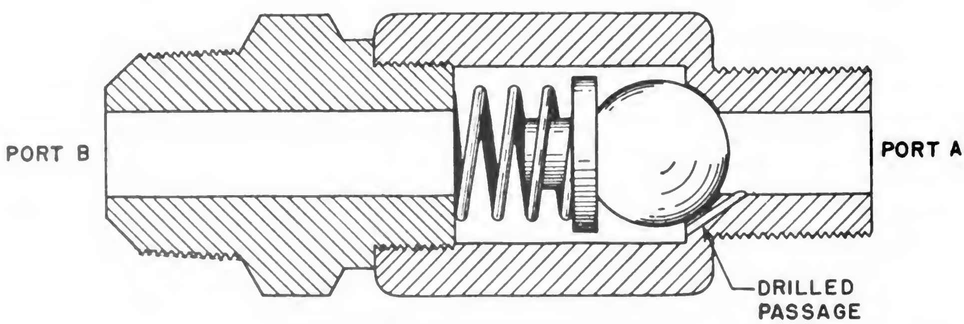


Figure 33. Orifice check valve.

b. Description. The unit shown in figure 33 is essentially a check valve with a small hole drilled through the seat. Oil entering port *A* moves the ball off its seat and flows out of port *B*. Oil entering port *B* holds the ball on its seat. However, a small amount of oil can flow through the drilled passage and out of port *A*. In a cone type orifice check valve, the hole is usually drilled through the cone.

25. METERING CHECK VALVE. a. Purpose. The metering type of check valve serves the same purpose in a system as an orifice check valve. It is, however, adjustable, while an orifice check valve is not.

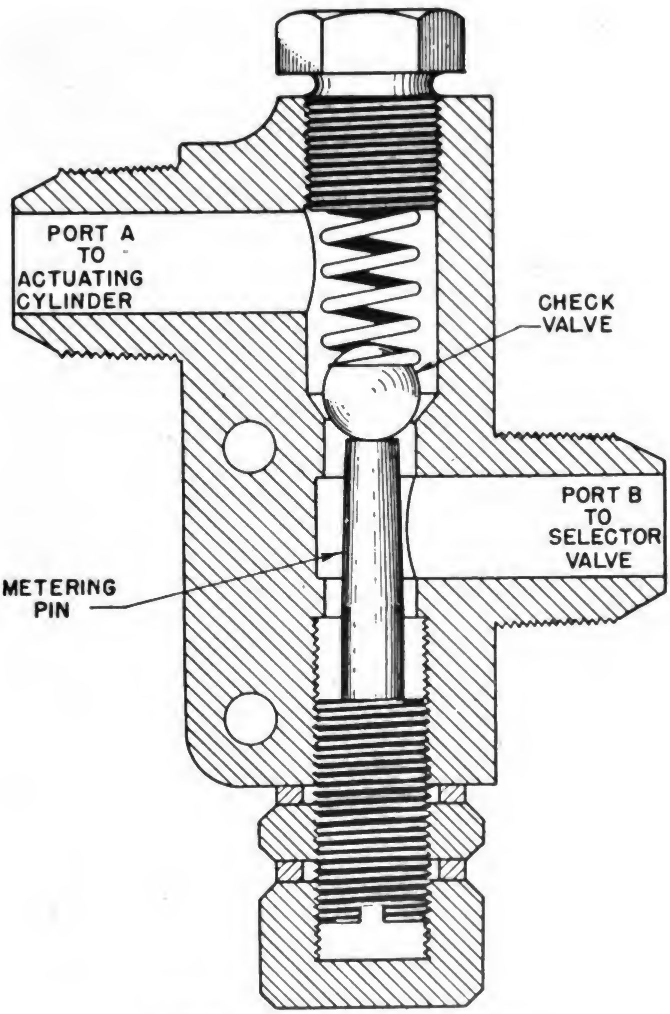


Figure 34. Metering check valve.

b. Description. The unit shown in figure 34 consists of a housing, a check-valve assembly, and a metering pin. This pin is adjusted to hold the ball slightly off its seat. Oil entering port *B* forces the ball away from its seat and flows out of port *A* to the actuating cylinder. When the flow of oil is reversed, oil returning from the actuating cylinder must flow through

the small opening between the ball and its seat, as shown in figure 34. The rate at which oil may return from the actuating cylinder may be varied by changing the size of the opening between the ball and its seat. This may be done by screwing the metering pin in or out.

26. LINE DISCONNECT VALVE. a. Purpose. The purpose of the line disconnect valve is to eliminate the need for draining the entire hydraulic system when the engine or power pump is changed. It is used in hydraulic lines which are periodically disconnected.

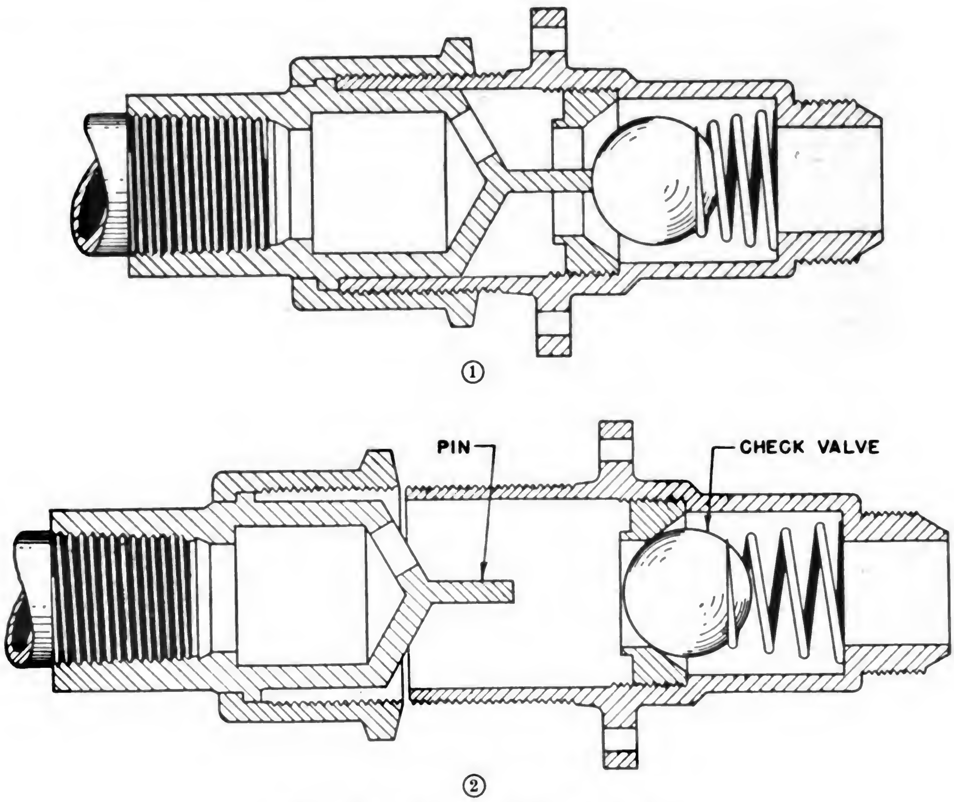


Figure 35. Line disconnect valve.

b. Description. The unit consists of two parts. A check valve is located in one of these parts. A pin is mounted in the other part. When the two parts are connected as shown in figure 35①, the check valve is held off its seat by the pin and oil can flow freely in either direction. When the two parts of the unit are disconnected as shown in figure 35②, the check valve seats and holds oil in the line in which it is installed. Some line disconnects contain a check valve in each part. When this type of unit is disconnected, both ends of the line are sealed.

27. BYPASS CHECK VALVE. a. Purpose. The bypass check valve is essentially a check valve which may be manually opened to allow free flow in both directions. It is usually installed between the accumulator and hand

pump connections, so that the output of the hand pump may be diverted into the accumulator.

b. Description. A bypass valve consists of a housing with two ports, a check valve, a pin, and an operating handle. The pin extends from the housing and is attached to the handle. Under normal operating conditions the unit will be in the position shown in figure 36①. In this position it will function as an ordinary check valve. Oil entering port *A* moves the ball off its seat and flows out of port *B*. If the handle is moved to the opposite position, the pin holds the ball off its seat and oil can flow in either direction. This position of the unit is shown in figure 36②.

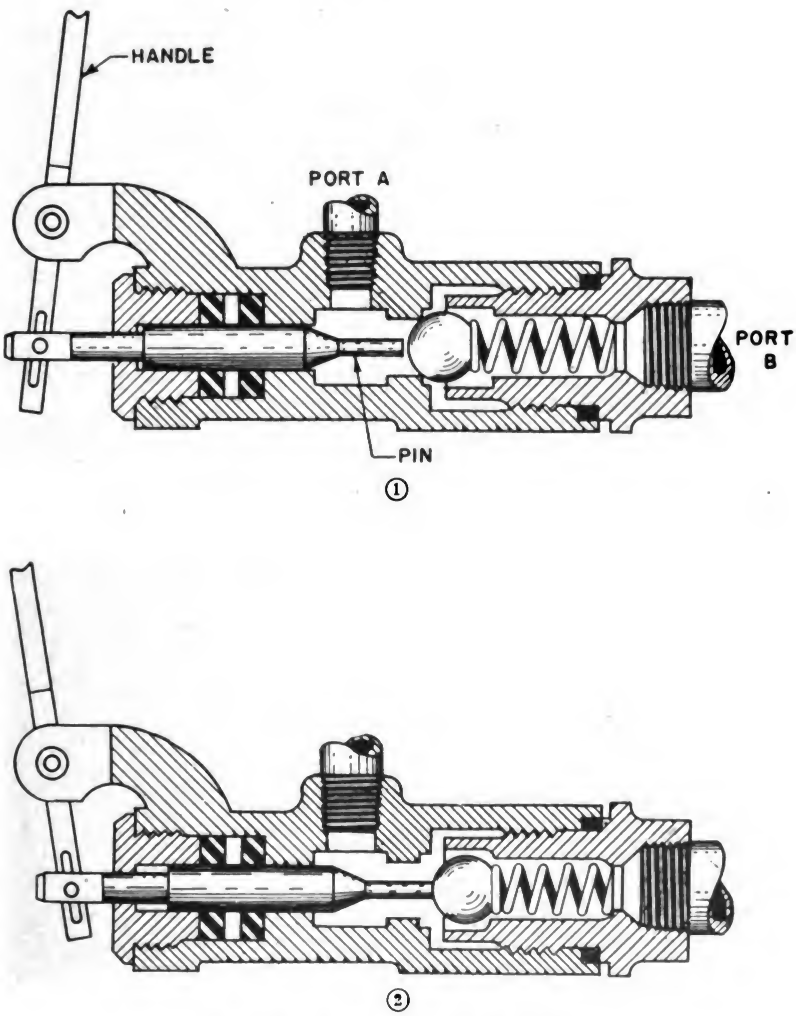
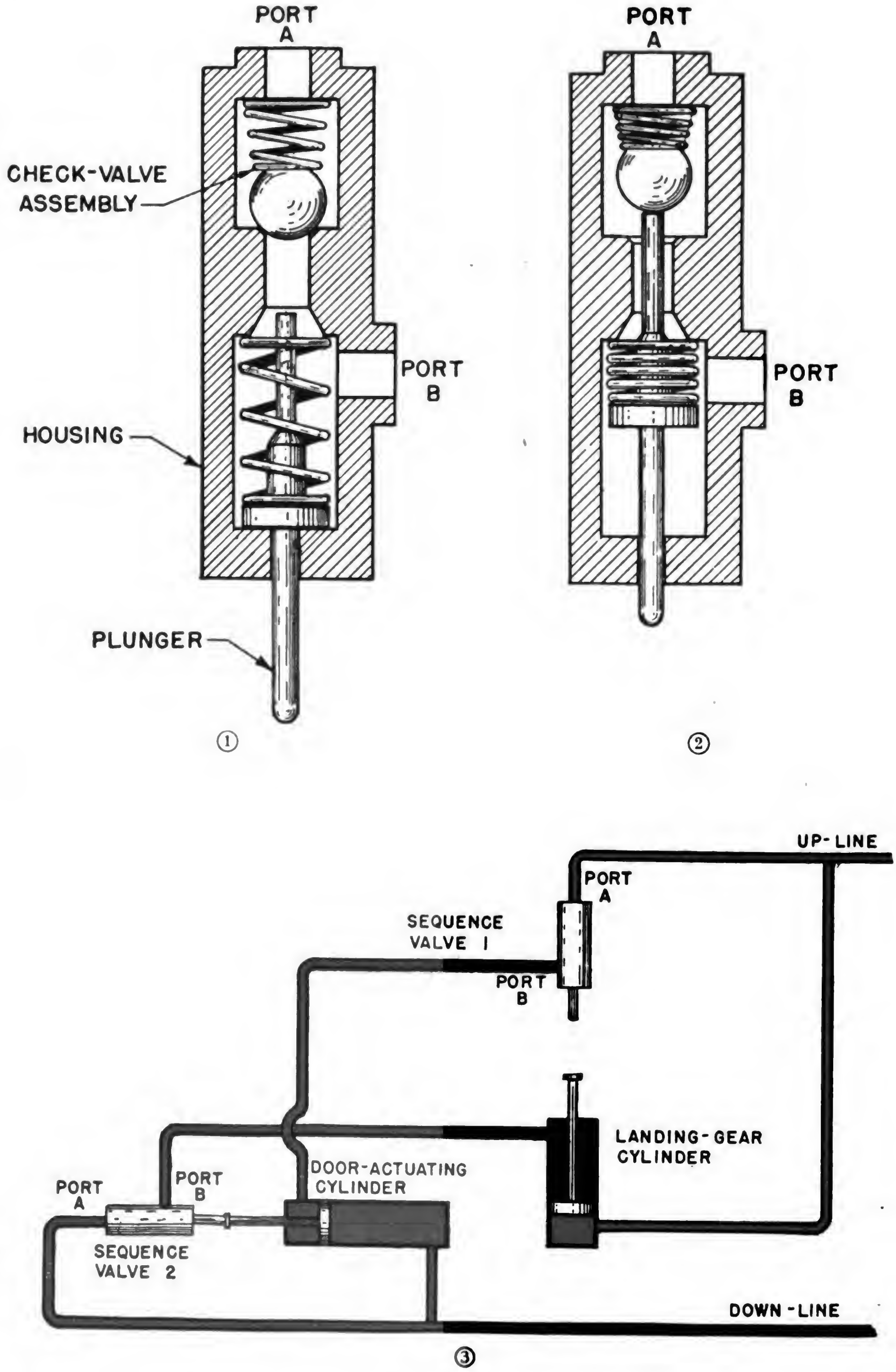


Figure 36. Bypass check valve.

28. SEQUENCE VALVE. a. Purpose. The function of the sequence valve is to cause one hydraulic operation to follow another in a definite order or sequence. This unit is also called a "timing valve" or "load-and-fire" check valve.



● *Fluid under pressure.* ● ***Fluid under atmospheric pressure.***

Figure 37. ***Sequence valve.***

b. Description. The unit is essentially a bypass check valve which is operated automatically. It consists of an outside housing in which there are two ports, *A* and *B* figure 37①. In one end of the housing is a plunger, which extends to the outside. When this plunger is pushed in, it pushes the ball off its seat.

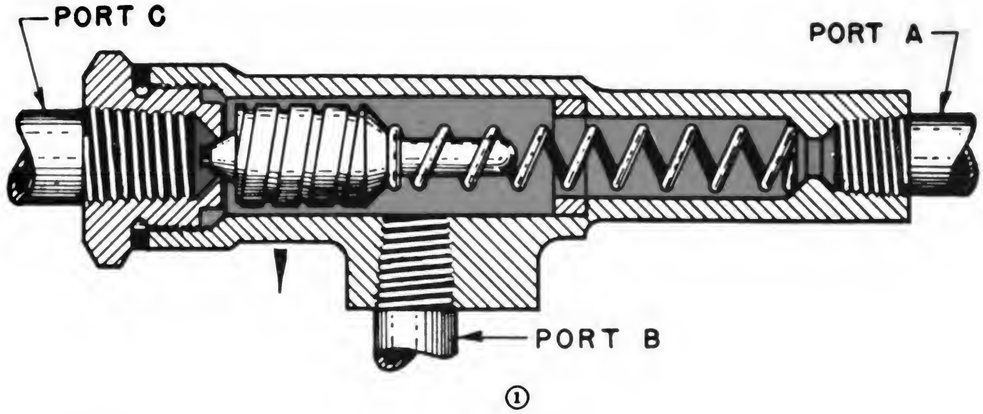
c. Operation. The sequence valve is mounted in such a position that motion of some part of the mechanism, for example the landing gear, will force the plunger in when the mechanism reaches the end of its stroke. A typical installation is shown in figure 37③. Port *A*, valve 1, is connected to the landing gear up-line and port *B* is connected to the landing gear door-actuating cylinder. Pressure entering port *A* holds the ball on its seat, and fluid cannot get to the door-actuating cylinder. This position of the unit is shown in figure 37①. As the landing gear reaches the full up position, some part of the landing gear mechanism strikes the plunger and pushes the ball off its seat. This position of the unit is shown in figure 37②. Oil can then flow by the ball and out of port *B* to the door-actuating cylinder, and close the door. Reversal of pressure application automatically reverses the sequence of operation. Port *B*, valve 2, is connected to the landing-gear actuating cylinder. Pressure entering port *A* holds the ball on its seat, and fluid cannot reach the landing-gear actuating cylinder. As the door reaches the full open position, some part of the door mechanism strikes the plunger on valve 2 and pushes it in. This pushes the ball off its seat, and oil can then flow out of port *B* to the actuating cylinder and lower the landing gear.

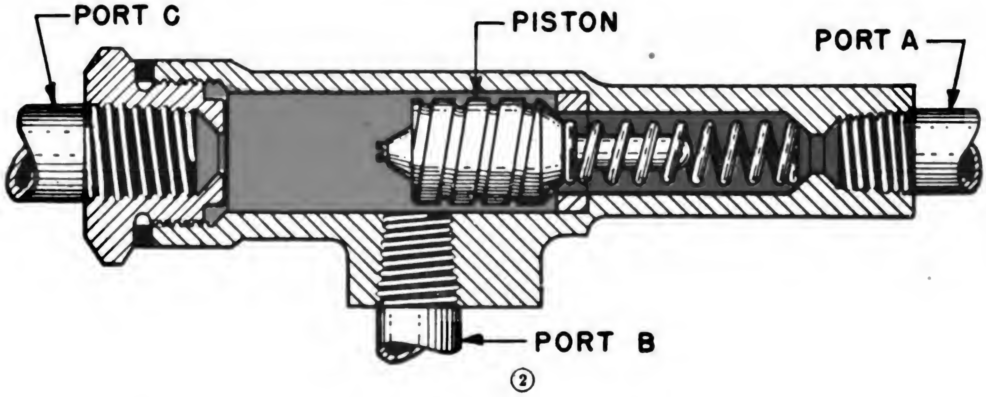
29. SHUTTLE VALVE. a. Purpose. The purpose of the shuttle valve is to direct oil automatically from either the normal source or the emergency source to the actuating cylinder. This unit is also used to direct air from the emergency source to the actuating cylinder. During emergency operation, the port connected to the normal operating line will be closed and there will be no loss of oil even if there is a leak in the normal operating line.

b. Description. The housing of the shuttle valve has three external ports. Port *A* (fig. 38) is located at one end of the body, and port *C* at the other end. These are both inlet ports. The common outlet, port *B*, is located midway between ports *A* and *C*. Inside the housing is a spring-loaded piston which functions as a check valve when forced to either end of the housing.

c. Operation. (1) The piston is spring loaded to close port *C* during normal operation. Under these conditions an open passage is maintained between ports *A* and *B*, as indicated in figure 38①.

(2) During emergency operation, oil enters port *C* and forces the piston to the opposite end of the housing. The piston seals the normal operating port *A*, and oil flowing in port *C* must flow out of port *B* to the actuating cylinder as indicated in figure 38②.





● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*
Figure 38. Shuttle valve.

30. CROSS-FLOW VALVE. a. Purpose. The function of the cross-flow valve is to bypass oil from the landing gear upline to the downline when the gear is being extended. When the landing gear is released, its weight causes it to fall so rapidly that oil cannot fill in behind the piston in the landing-gear actuating cylinder. The weight of the landing gear also causes pressure to build up on the opposite side of the piston. The cross-flow valve permits oil to flow from the up side of the piston to the down side and thus allows the gear to fall more easily and with an even motion.

b. Description. There are two types of cross-flow valves. One type functions automatically during normal operation of the gear. The other type is manually operated and is used only during emergency operation of the gear.

(1) The automatic type valve (fig. 39) consists of a housing with three ports, a check valve, a restrictor, and a piston which functions as a check valve. Oil from the up side of the piston enters port *A*, moves the piston to the right, and flows through the check valve and out of port *C* to the downline. This position of the unit is shown in figure 39①. When the output of the power pump "catches up" with the piston, pressure in the downline

seats the check valve and forces the landing gear to the full extended position. The remainder of the oil in the up side of the cylinder will flow through the restrictor and out of port *B*. When the landing gear is being retracted, oil under pressure entering port *B* moves the restrictor to the left and flows out port *A* to the actuating cylinder. This position of the unit is shown in figure 39②.

(2) The manually operated cross-flow valve is also called an "emergency unloading" or "dump" valve. It accomplishes the same thing during emergency operation that the automatic unit does during normal operation. The

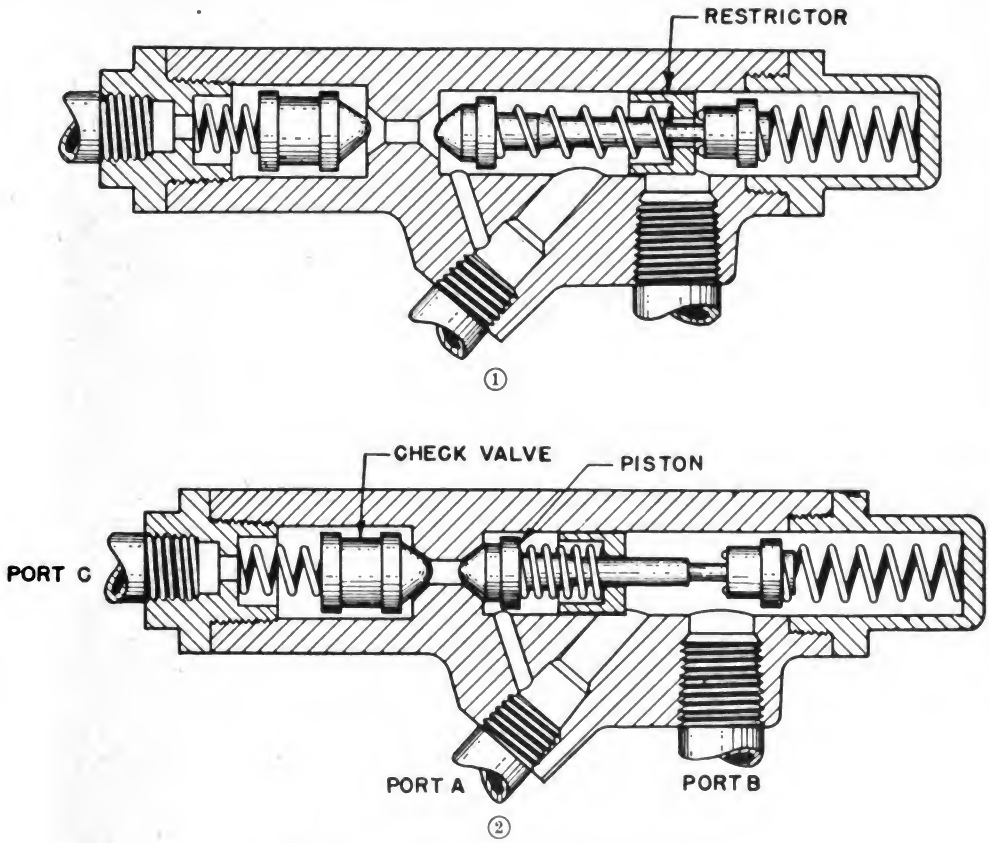


Figure 39. Automatic cross-flow valve.

unit shown in figure 40 consists of a two-port housing, a check-valve assembly, a plunger, and an operating handle. Port *A* is connected to the downline. A check valve is installed between port *A* and port *B*. The plunger is located in line with the check valve. During normal operation, the check valve in the unit is seated. For emergency operation, the handle is moved to the left. This movement forces the plunger inward and holds the check valve in the unit open. Oil can then flow from the upline, through the unit, and into the downline. The check valve installed between port *A* and the downline keeps oil under pressure in the downline from escaping through the unit and into the upline.

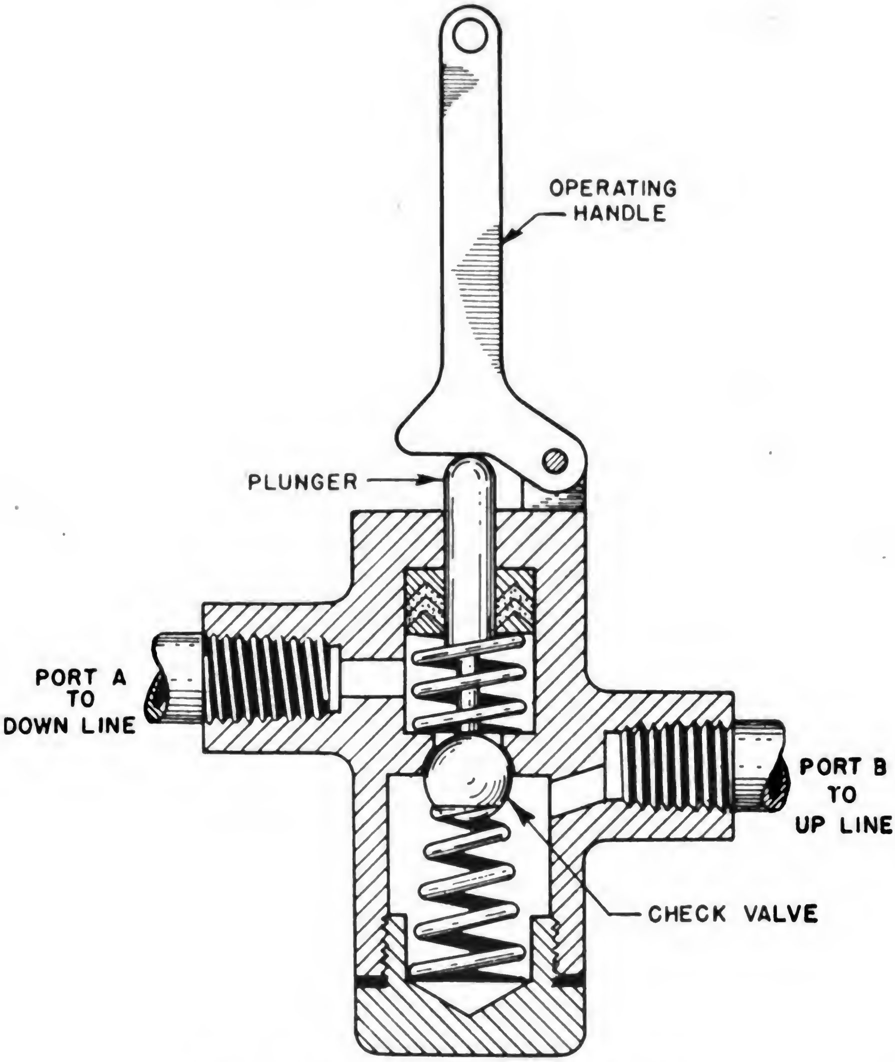
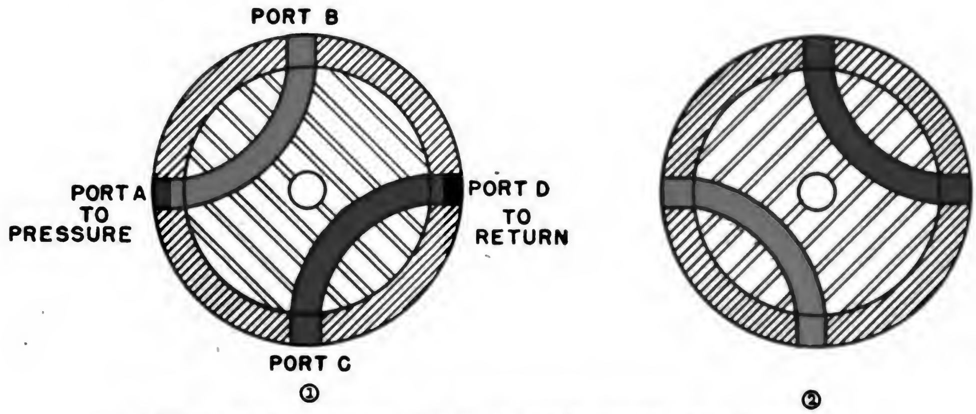


Figure 40. Manually operated cross-flow valve.

31. SELECTOR VALVE. a. Purpose. The purpose of a selector valve is to control the direction of operation of a mechanism. The unit does this by directing oil under pressure to the desired end of the actuating cylinder and at the same time directing oil from the opposite end of the cylinder to the reservoir.

b. Rotor type selector valve. The selector valve shown in figure 41 is a four-port valve consisting of a housing and a rotor. The four ports in the housing are 90° apart. The rotor, which is attached to a handle, contains two channels which connect adjacent ports. The inport (from the pressure manifold) and the outport (to the return manifold) are always opposite each other. The other ports are connected to the opposite ends of an actuating cylinder. Oil entering port *A* (fig. 41①) is directed out of port *B* to one end of the actuating cylinder. Oil from the other end of the cylinder comes in port *C* and is directed through port *D* to the return line.

If the rotor is turned 90° as shown in figure 41②, the flow into and from the actuating cylinder is reversed. If the rotor is turned 45°, the channels do not align with the ports and all flow is stopped. This position is called the neutral position.

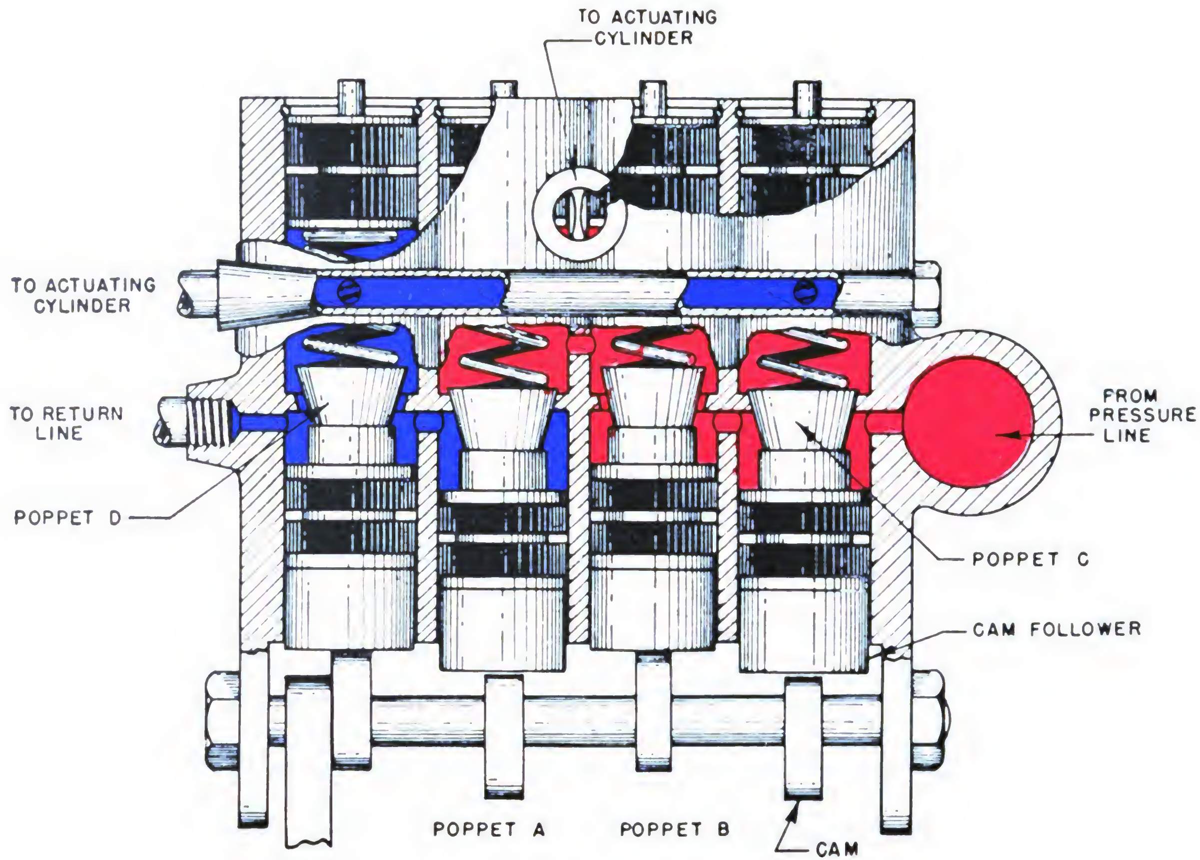


● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 41. Rotor type selector valve

c. Poppet type selector valve. Essentially the poppet type selector valve consists of a housing, a series of spring-loaded poppets, and a camshaft which is attached to an operating handle. A typical unit is shown in figure 42. The housing has a pressure port, a return port, and two alternating ports. The cams on the shaft are arranged to operate alternate poppets together. When the unit is in the position shown in figure 42, poppets *A* and *C* are held closed by springs, and poppets *B* and *D* are held open by the cams. Oil entering the pressure port flows by poppet *B* and out of the alternating port to the actuating cylinder. Oil from the other end of the actuating cylinder flows in the other alternating port, around poppet *D*, and out of the return port to the reservoir. In order to reverse the flow of oil and move the mechanism attached to the actuating cylinder in the opposite direction, the handle must be moved to the opposite position. This will rotate the camshaft, and poppets *A* and *C* will then be held open by cams and poppets *B* and *D* will be held closed by the springs. The flow previously described is reversed, and the mechanism will be moved in the opposite direction. When the handle is placed in the neutral position, all poppets will be seated and all flow stopped.

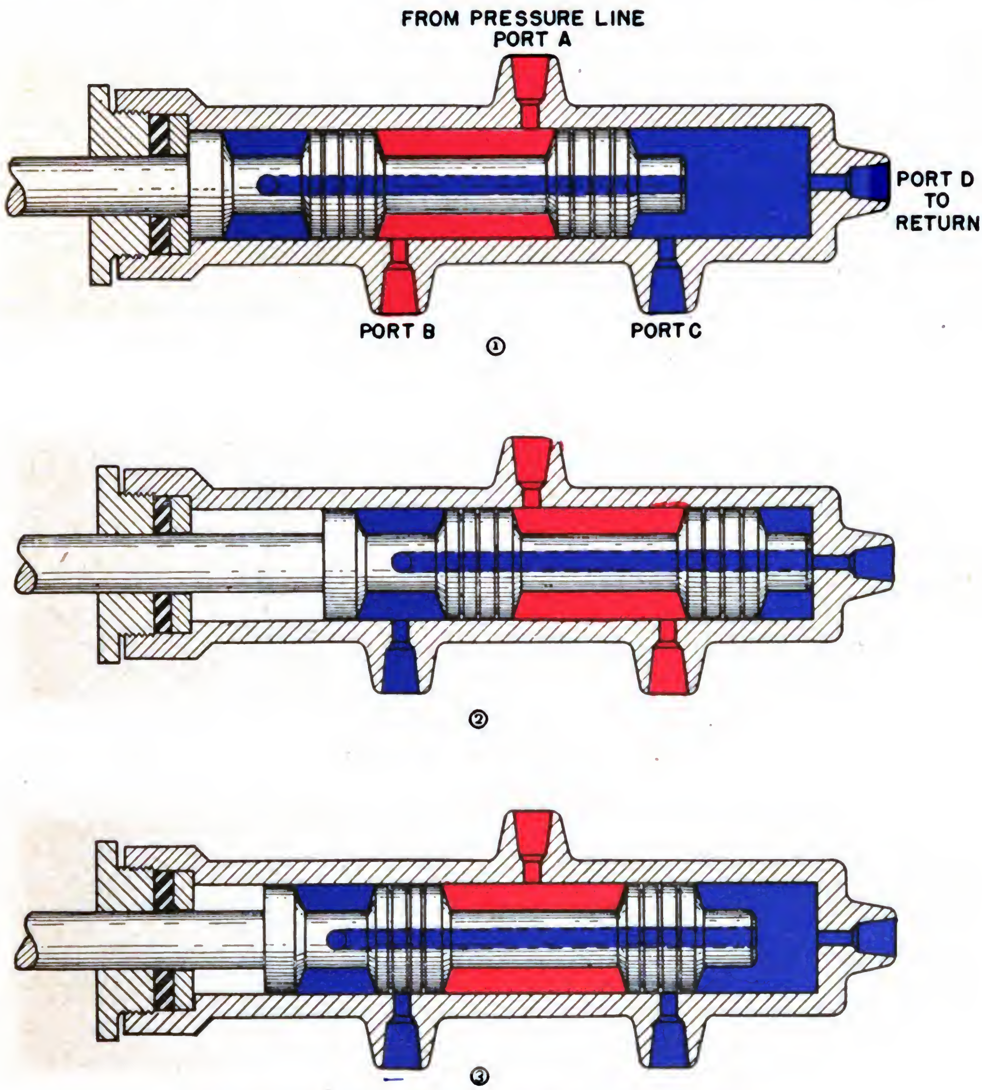
d. Piston type selector valve. A typical piston type selector valve (fig. 43) consists primarily of a hollow spool-shaped piston within a housing which has four ports. The piston has drilled passages connecting the hollow part to each end of the housing. In the position shown in figure 43① oil entering the pressure port *A* flows around the cut-away part of the piston and out of port *B* to the actuating cylinder. Oil from the opposite end of the cylinder flows in port *C* and out the return port D to the reservoir. When the piston moves to the position shown in figure 43②, the flow of oil



Fluid under pressure. ***Fluid under atmospheric pressure.***

Figure 42. Poppet type selector valve.

to and from the actuating cylinder is reversed. Oil under pressure enters port *A* and flows out of port *C* to the actuating cylinder. Oil from the opposite end of the cylinder flows in port *B*, through the hollow piston, and out port *D* to the reservoir. If the piston is moved to the position shown in figure 43③, both alternating ports are closed and the valve is in the neutral position.



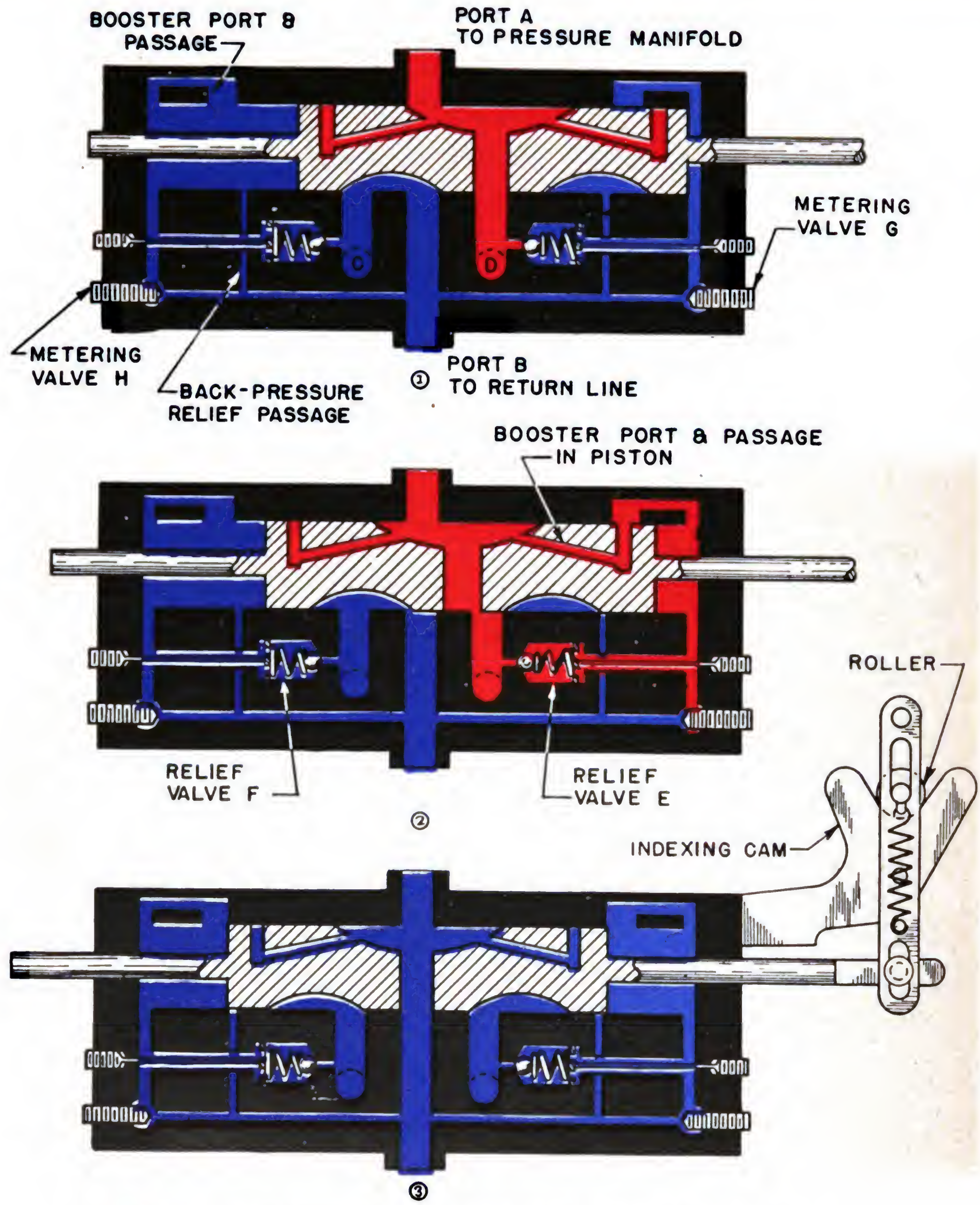
Fluid under pressure. *Fluid under atmospheric pressure.*

Figure 43. Piston type selector valve.

e. Open-center selector valve. Like other selector valves, the open-center type provides a means of directing oil under pressure to one end of an actuating cylinder and at the same time directing oil from the other end of the cylinder to the return line. The advantage of the open center type is that the valve automatically returns to neutral when the actuating cylinder reaches the end of its stroke. When this unit is in the neutral

position, the output of the power pump is directed through the unit to the reservoir.

(1) *Description.* There are four external ports in the housing of the open-center selector valve. Port *A* (fig. 44) is the pressure port; port *B*, the return port, and ports *C* and *D*, alternating ports. Inside the housing



Fluid under pressure. ***Fluid under atmospheric pressure.***

Figure 44. Open-center selector valve.

is a steel sleeve which forms a cylinder for the valve piston. This piston has passageways which correspond with the sleeve ports. Two adjustable relief valves and two adjustable metering valves are built into the housing. An external adjusting screw is provided for each of these valves.

(2) *Operation.* When the unit is manually moved from the neutral position shown in figure 44③ to the position shown in figure 44① oil entering port *A* goes through the passage in the piston and out of port *D*. Port *C* is connected to the return port *B* by the cut-away section of the piston. When the mechanism reaches the end of its stroke, pressure will suddenly build up and open the relief valve *E*. Oil passing through the open relief valve is directed to the right end of the piston. The rapid escape of oil from this end of the cylinder is prevented by the metering valve *G*. Oil in the other end of the cylinder is free to escape through the back pressure relief passage. The piston will therefore be moved toward the left by pressure which builds up on the end of the piston. When the piston is moved far enough, the neutral booster ports in the piston and the housing will be lined up. This position of the unit is shown in figure 44②. Oil under full system pressure from port *A* will then be directed through the passages in the piston and the housing to the right end of the piston. This pressure will quickly move the piston to the neutral position and connect ports *A* and *B*. The output of the pump is then directed to the reservoir. This position of the unit is shown in figure 44③. Automatic return to this position from the position of figure 44② is assisted by the cam-and-lever assembly. Operation of the valve when moved to the opposite setting is the same as just outlined, except that port *C* is connected to the pressure line, and relief valve F and metering valve *H* will function to provide the pressure for the automatic return to the midway position.

f. Surface control booster unit. This unit is essentially a selector valve and an actuating cylinder built into the same housing. Its purpose is to multiply the distance of movement of the movable control surfaces by the exact amount necessary to compensate for the loss of distance which would normally occur in gaining mechanical advantage.

(1) *Description.* The unit consists essentially of a three-port housing which contains a piston type selector valve assembly, and actuating cylinder assembly and two gust lock valve assemblies. One port is connected to the pressure manifold, another port is connected to the return manifold, and the third port is connected to the gust lock control valve. Normally the selector valve is in neutral. Movement of the selector valve piston directs oil to one side of the actuating cylinder piston and at the same time connects the other side of the piston to the return port.

(2) *Operation.* This unit is mounted in the surface control system. The selector valve piston and the actuating cylinder piston are connected to the surface control through bell cranks attached to the piston rods. The housing is connected to the control surface through another bell crank. The difference in length of the bell cranks gives a mechanical advantage. Movement of the control causes the actuating cylinder piston to move. As the selector valve is in neutral at the beginning of the movement, the actuating cylinder piston and the housing are locked together by the entrapped hydraulic fluid. Therefore the whole unit will move, and, as the housing is

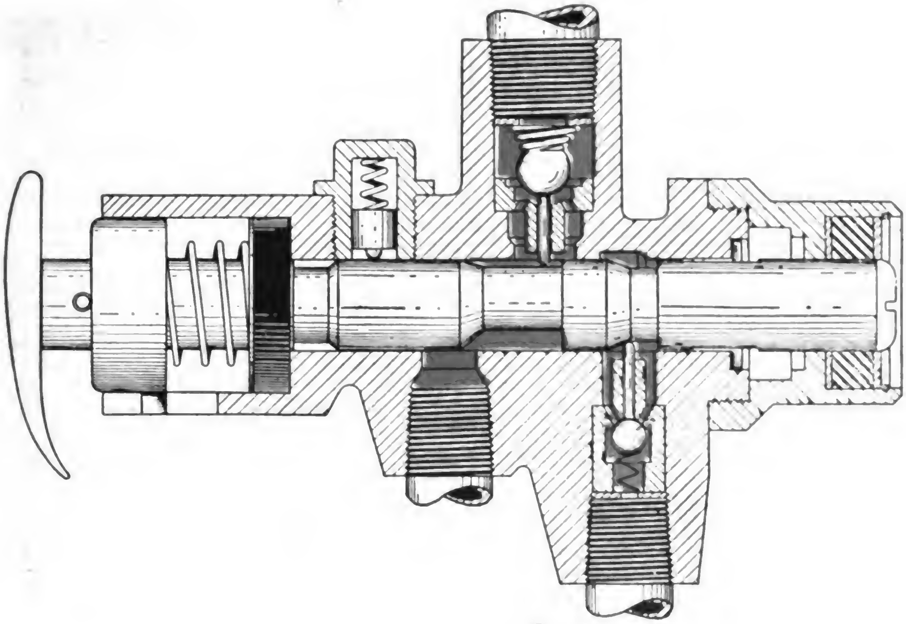
connected to the control surface, the surface will be moved. However, the difference in length of the bell cranks causes the selector valve piston to move farther than the housing. This moves the selector valve out of the neutral position and connects the pressure port to an internal passage leading to one end of the actuating cylinder, and at the same time, connects the passage from the other end of the actuating cylinder to the return port. As the actuating cylinder piston and the selector valve pistons are connected to the control, they will be held stationary. Therefore, the housing will be moved by oil under pressure (and move the control surface to which it is attached) until the selector valve is again in neutral. The selector valve will not reach the neutral position until the bell cranks are again in the same relative position they were in before the movement started. Therefore, even though force is gained by the use of the bell cranks, no distance of movement will be lost. If the booster unit should fail, a stop in the bell crank connected to the control will strike the bell crank connected to the control surface and the surface may be moved manually.

(3) *Locking.* The control surfaces may be locked by movement of the gust lock control valve, which is manually controlled by the parking-brake lever. Movement of this valve directs hydraulic fluid under pressure to the gust lock valves. These units are essentially spring-loaded pistons which may be made to close the internal passages between the selector valve and the actuating cylinder. The pistons are normally held off their seats by the springs, and the passages are open. When pressure is applied to the pistons, they seat and trap fluid on both sides of the actuating cylinder piston. As this oil cannot compress and cannot get out, the booster mechanism, the control, and the control surface will be locked in the position they occupied when the gust lock valve was closed.

32. GUN-CHARGER CONTROL VALVE. a. Purpose. The purpose of the gun-charger control valve is to prepare quickly and remotely a machine gun or cannon for firing by directing pressure to an actuating cylinder which operates the gun breech through its first cycle. The unit may be used also to safety the gun by trapping oil in the actuating cylinder at the end of the first half of the cycle.

b. Description. The unit shown in figure 45 consists essentially of a three-port housing, two check valves *A* and *B*, an operating handle, and a plunger. Check valve *A* is located in the inport and check valve *B* in the cylinder port. A pin is located between each of the check valves and the plunger. A release valve and stop are located in one end of the plunger. Shoulders on the stop extend through holes in the plunger. A small spring-loaded detent plunger is mounted in the housing.

c. Operation. When the unit is in the disengaged position, oil cannot be transmitted through the valve to the actuating cylinder because check valve *A* is closed. To charge the gun, the handle must be turned 140° to the firing position and pushed inward. The rotation causes the cam ar-



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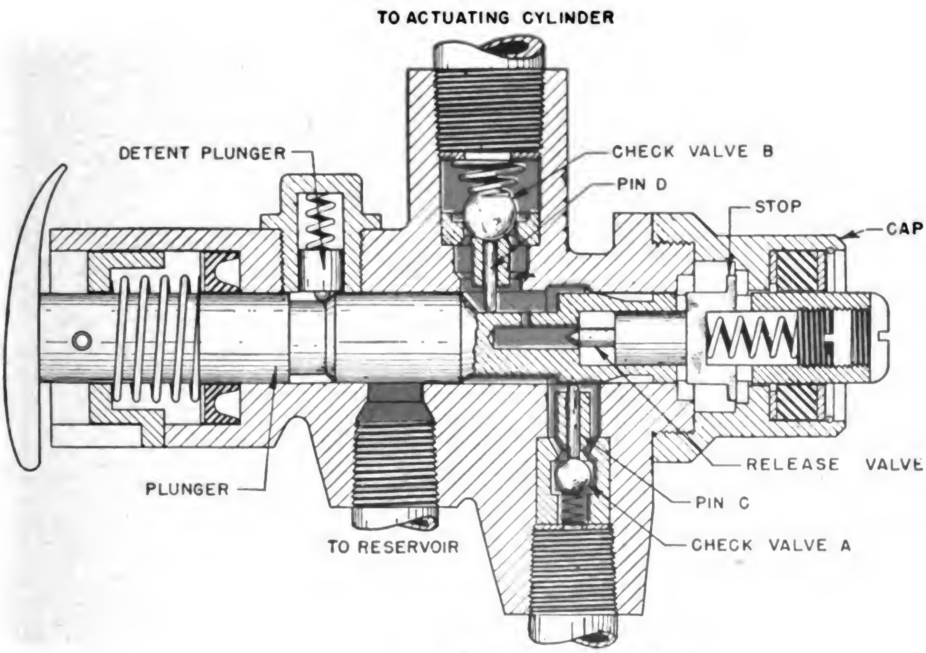

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● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 45. Gun-charger control valve.

rangement on the plunger to push the pin D and unseat check valve B. As the plunger is pushed inward, the large part of the plunger closes the return port and pin C rides up the sloping shoulder of the plunger and unseats check valve A. Oil under pressure then flows through check valve A, around the small part of the plunger, and through check valve B to the gun-charger actuating cylinder, and thus opens the breech.

(1) When the piston in the gun-charger actuating cylinder reaches the end of its stroke, pressure (acting through holes in the plunger) moves the release valve off its seat. This movement of the valve pushes the shoulders of the stop against the cap. Since the release valve cannot move any farther, pressure acting on the inner area of the plunger pushes the plunger outward, separating it from the release valve. Thus the plunger is forced out of engagement with the detent plunger and is moved to the left. This position of the unit is shown in figure 45①. In this position check valve A is closed (preventing additional pressure from entering the unit). The return port is open, and check valve B is off its seat. This permits the spring-loaded piston in the actuating cylinder to force the oil from the actuating cylinder through the control valve to the return line. As the oil leaves the actuating cylinder, the breech is closed and the gun is charged. Subsequent charging of the gun is accomplished by recoil; hence further operation of the control valve is unnecessary unless the gun jams or it is desired to safety the gun.

(2) If the pilot desires to safety the gun, the handle is placed in the safety position and then pushed in. This position of the unit is shown in figure 45②. This rotates the cam away from pin D, allowing check valve B to seat, and at the same time forces check valve A off its seat. With the unit in this position, oil can flow through the unit to open the breech but cannot return, because check valve B is not held off its seat. Thus the breech is hydraulically locked in the open position by oil trapped in the actuating cylinder. The gun can be changed from the safety to the fire position by rotating the handle 140°. Pin D holds valve B off its seat and allows the trapped oil to return to the reservoir as shown in figure 45①.

SECTION V

PRESSURE CONTROL VALVES

33. GENERAL. The purpose of pressure-control valves is to limit or control the pressure in a hydraulic system. They are usually safety devices which prevent damage to the various parts of the system. Some units are designed to trap oil under pressure in a section of the system.

34. RELIEF VALVE. a. Purpose. The function of a relief valve is to prevent pressure in a section of the hydraulic system from going above a predetermined value. It does this by bypassing oil from the pressure side of the system to the return side. Relief valves are used to limit the pressure developed by power pumps, hand pumps, temperature expansion, etc.

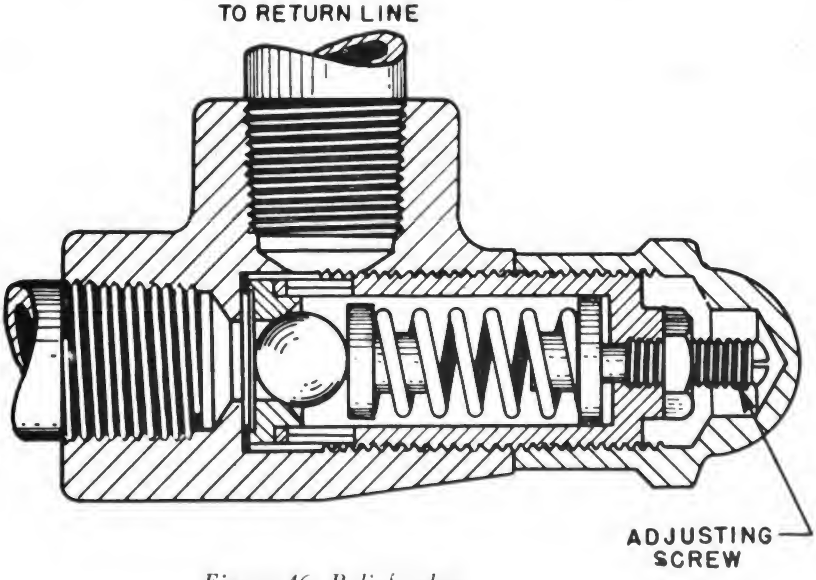


Figure 46. Relief valve.

b. Description. Relief valves consist of a two-port housing, a ball or cone which is held on its seat by a strong spring, and an adjusting screw. A typical relief valve is shown in figure 46. Oil cannot pass from port *A* to port *B* as long as the ball is held on its seat. When pressure at port *A* becomes great enough to overcome the force of the spring, it moves the ball off its seat. This allows oil to escape to the return line through port *B*.

Thus pressure can never go above the value necessary to overcome the force of the spring. If oil is being pumped into the line connected to port *A* a steady pressure will be maintained at the pressure setting of the valve. This is true because as fast as the pressure is relieved the ball will reseat and the pump will again build up pressure high enough to open the valve. In actual practice the ball will "flutter" on and off its seat as long as oil is being delivered by the pump.

35. PRESSURE CUT-OFF VALVE. a. Purpose. The pressure cut-off valve is usually used in conjunction with a hydraulic motor, and is installed between the selector valve and the motor. Its purpose is to stop

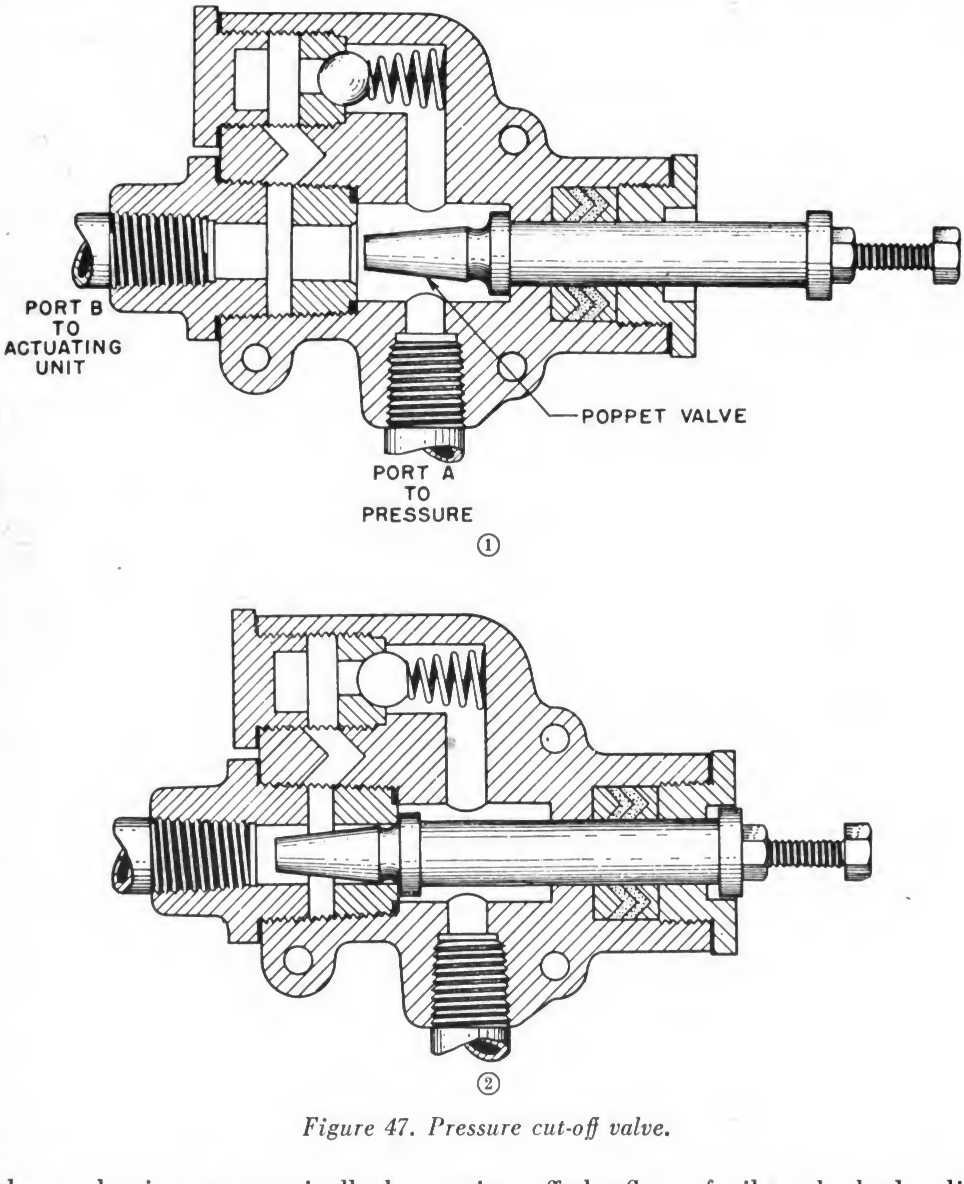


Figure 47. Pressure cut-off valve.

the mechanism automatically by cutting off the flow of oil to the hydraulic motor when the mechanism reaches the end of its travel.

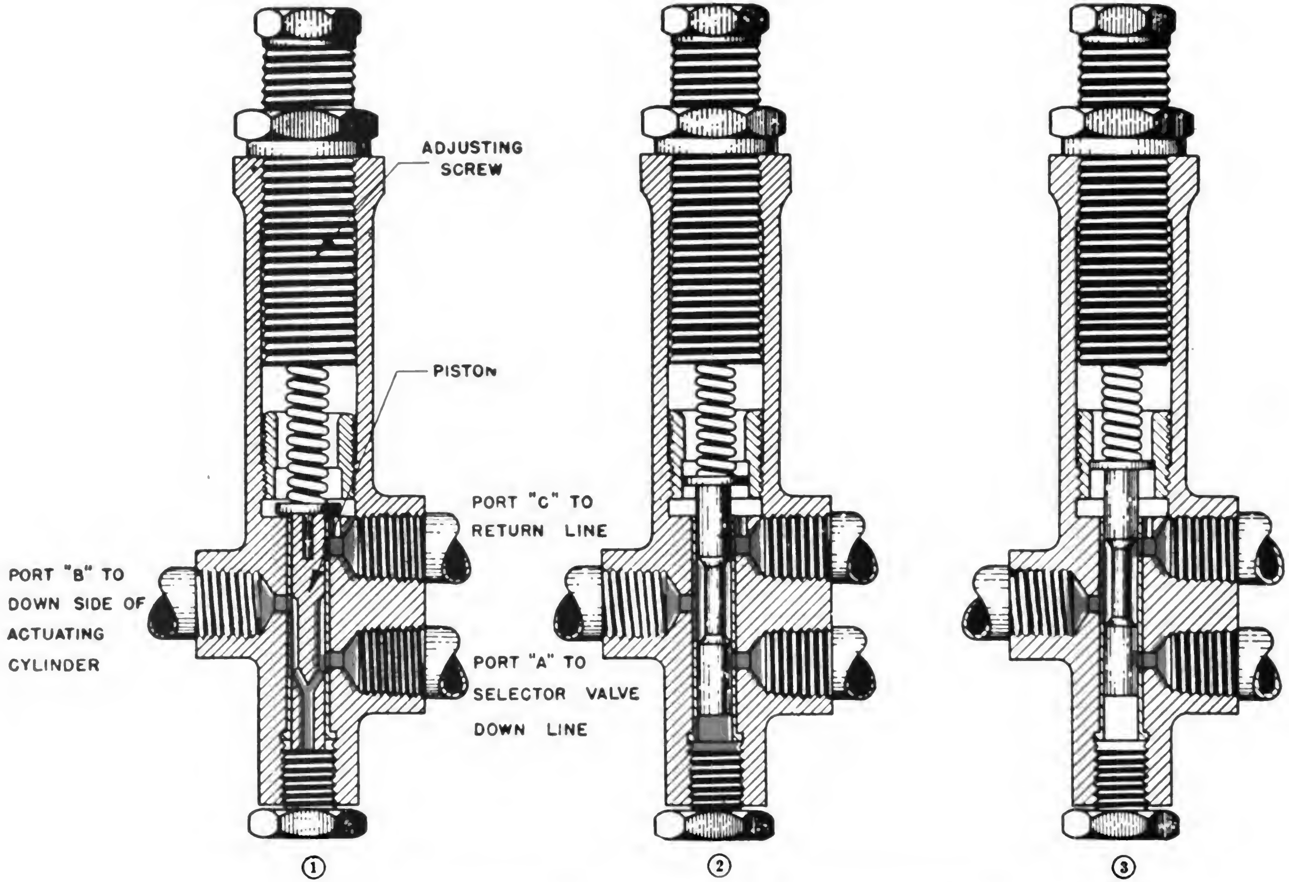
b. Description. A pressure cut-off valve is also called a "stop" or "travel-limit" valve. It consists essentially of a two-port housing, a check valve, and a tapered steel poppet valve which is connected to an external plunger. When the unit is in the position shown in figure 47①, oil flowing in port *A* flows out of port *B* to the actuating unit, which moves the mechanism. When the mechanism reaches the end of its travel, the poppet is forced to the extreme inward position by some part of the mechanism and the valve is entirely closed. This cuts off the flow of oil to the actuating unit and thus stops the movement of the mechanism. This position of the unit is shown in figure 47②. The check valve allows free flow of oil from port *B* to port *A* when the movement of the mechanism is reversed. Usually a pressure cut-off valve is used to stop the mechanism at each extremity of its travel. The amount of travel of the mechanism may be adjusted by means of the screw in the end of the plunger.

36. FLAP-OVERLOAD VALVE. a. Purpose. The function of the flap-overload valve is to prevent lowering of the flaps to the full DOWN position when the airspeed is high enough to damage the flaps or the flap linkage. If the flaps are partially lowered at normal speed, this unit automatically permits them to move up if the speed is increased to a value which may damage the flaps.

b. Description. A flap overload valve consists of a three-port housing, a spring-loaded spool-shaped piston, and an adjusting screw. Two external check valves are always used in conjunction with this unit. A typical installation is shown in figure 48④.

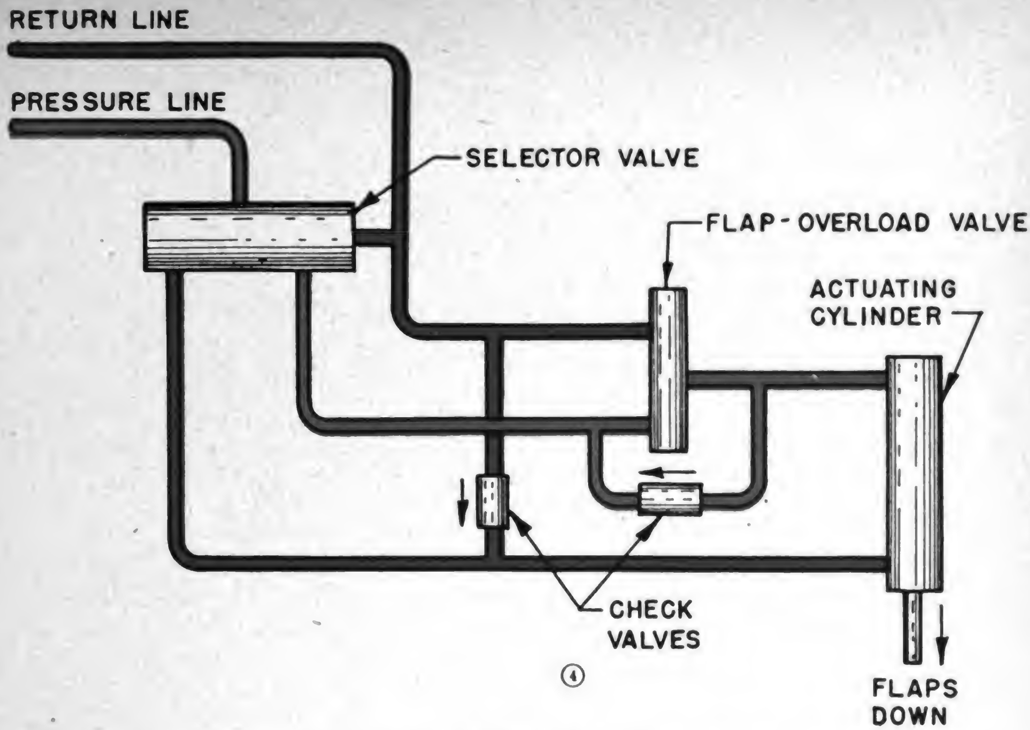
c. Operation. (1) During the normal operation the unit will be in the position shown in figure 48①. Oil from the selector valve enters port *A*, flows around the cut-away section of the piston and out of port *B* to the down side of the actuating cylinder and moves the flaps down. As the flaps move downward into the slipstream, the force resisting the downward movement increases. This causes the pressure in the downline and in the valve to increase. This pressure is transmitted to the bottom face of the piston through drilled passages in the lower end of the piston. If the flaps are being lowered at excessive airplane speeds, this pressure becomes great enough to overcome the force of the spring before the flaps reach the full DOWN position. The piston will then be moved up and port *A* will be closed by the shoulder on the bottom end of the piston. Since oil can no longer flow to or from the actuating cylinder, the flaps will remain stationary unless the speed of the airplane is increased or decreased. This position of the unit is shown in figure 48②.

(2) If the speed of the airplane is increased still more, the air load on the flaps, acting through the flap linkage, will tend to move the piston in the flap actuating cylinder back into the cylinder. As the oil is trapped in the



● ***Fluid under pressure.*** ● ***Fluid under atmospheric pressure.***

Figure 48. Flap-overload valve.



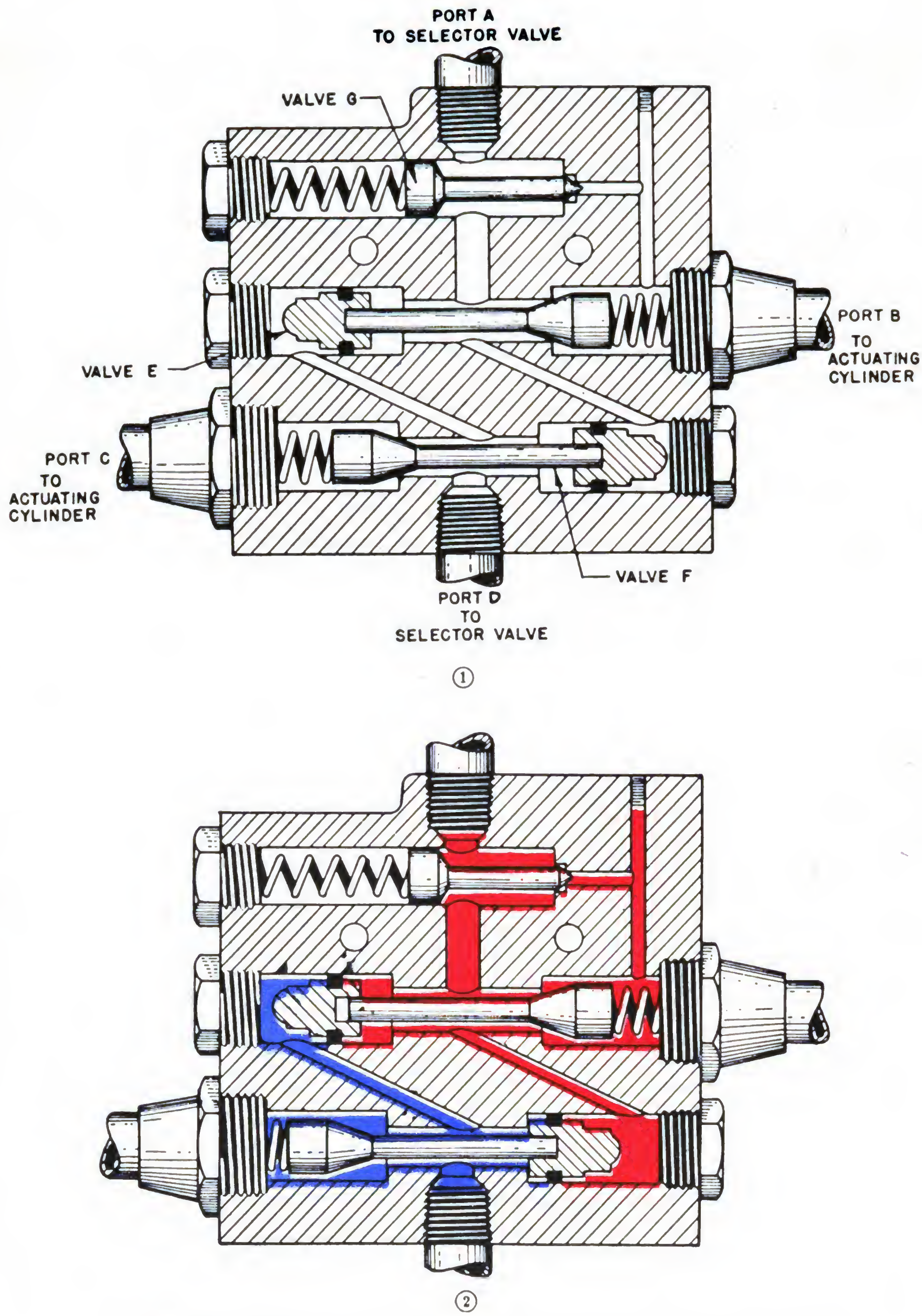
● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 48. Flap-overload valve—Continued.

downline, pressure in this line and in the flap overload valve will increase. When the pressure reaches the value for which the unit is adjusted, the cutaway section of the piston connects ports *B* and *C* and some of the oil in the down side of the cylinder can escape to the return line. (See fig. 48③.) The flaps will then move up until the pressure created by the airload drops below the value for which the unit is adjusted. The piston will then be moved down by the spring, port *C* will be closed, and the flaps will remain stationary unless the speed of the ship is again increased or decreased. A decrease in airspeed will reverse this procedure.

37. RATCHET VALVE. a. Purpose. The ratchet valve is used in the wing-flap system. When a "leak type" flap selector valve (a selector valve using a piston which is lapped in place rather than a piston equipped with sealing cups) is used in the system, pressure can escape through the selector valve. A ratchet valve (or a similar valve called an "auxiliary wing flap valve") is used with this type of selector valve to retain pressure in the flap actuating cylinder. This keeps the flaps from "drooping" when they are up (on the ground) and from creeping up when they are down (during flight).

b. Description. The unit is installed in the flap system between the selector valve and the actuating cylinder, with both alternating lines passing through it. It consists of a four-port housing containing three spring-loaded



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 49. Ratchet valve.

adjustable valves. Valve *G* (fig. 49①) is a temperature expansion relief valve. Valves *F* and *E* are essentially check-relief valves.

c. Operation. When the selector valve is in the UP position, oil under pressure from the selector valve enters port *A* and unseats valves *E* and *F*, as

shown in figure 49②. This oil can then flow out of port *B* to the actuating cylinder and move the flaps up. Oil from the opposite end of the actuating cylinder enters port *C* and flows around valve *F* and out port *D* to the return line through the selector valve. When the flaps reach the full UP position, valve *E* immediately seats. Even though the pressure applied at port *A* decreases (through the leak type selector valve), pressure will be retained in the actuating cylinder by valve *E*, and the flaps will remain up. When the selector valve is placed in the DOWN position, oil under pressure enters port *D*, opens valves *E* and *F*, and flows out of port *C* to the actuating cylinder. Return oil enters port *B* and flows around valve *E* and out of port *A* to the return line. When the flaps cease moving downward, valve *F* immediately seats and traps pressure in the actuating cylinder, thus holding the flaps down.

38. HYDRAULIC-PRESSURE SWITCHES. a. Purpose. The function of hydraulic pressure switches is to turn a switch on or off automatically in response to changes of pressure. There are two general types of switches:

(1) The pressure warning switch, which operates at a given pressure.

(2) The pressure switch, which may be adjusted to operate over a very wide range.

b. Pressure warning switch. (1) *Purpose.* The simple type of pressure warning switch is used to operate warning devices which indicate high or low pressure.

(2) *Description.* The unit shown in figure 50 includes a housing containing a spring-loaded piston and a switch. The housing has one port and an opening through which the wires to the switch are passed. The port is connected to the pressure manifold. The rod attached to the piston operates the switch.

(3) *Operation.* The switch in this unit is connected in series with the warning device. Oil under pressure from the pressure manifold compresses the spring and holds the piston up, as shown in figure 50②. When the unit is in this position, the switch contacts are separated and the switch is in the OFF position. If pressure drops below the value for which the unit is set, the spring will force the piston down and operate the switch as shown in figure 50①. This completes the electrical circuit, and the warning device will go into operation. This type of switch will go on or off within a very limited range.

c. Pressure switch. (1) *Purpose.* Where it is necessary to have a comparatively large difference between the pressure at which the switch is turned on and the pressure at which the switch is turned off, a pressure switch must be used.

(2) *Description.* The housing of the pressure switch has three external ports. Two of these ports, *A* and *B* (fig. 51) are connected to the pressure line between the power pump and the accumulator. Port *C* is connected to the return manifold. Within the housing are two pistons, *D* and *E*,

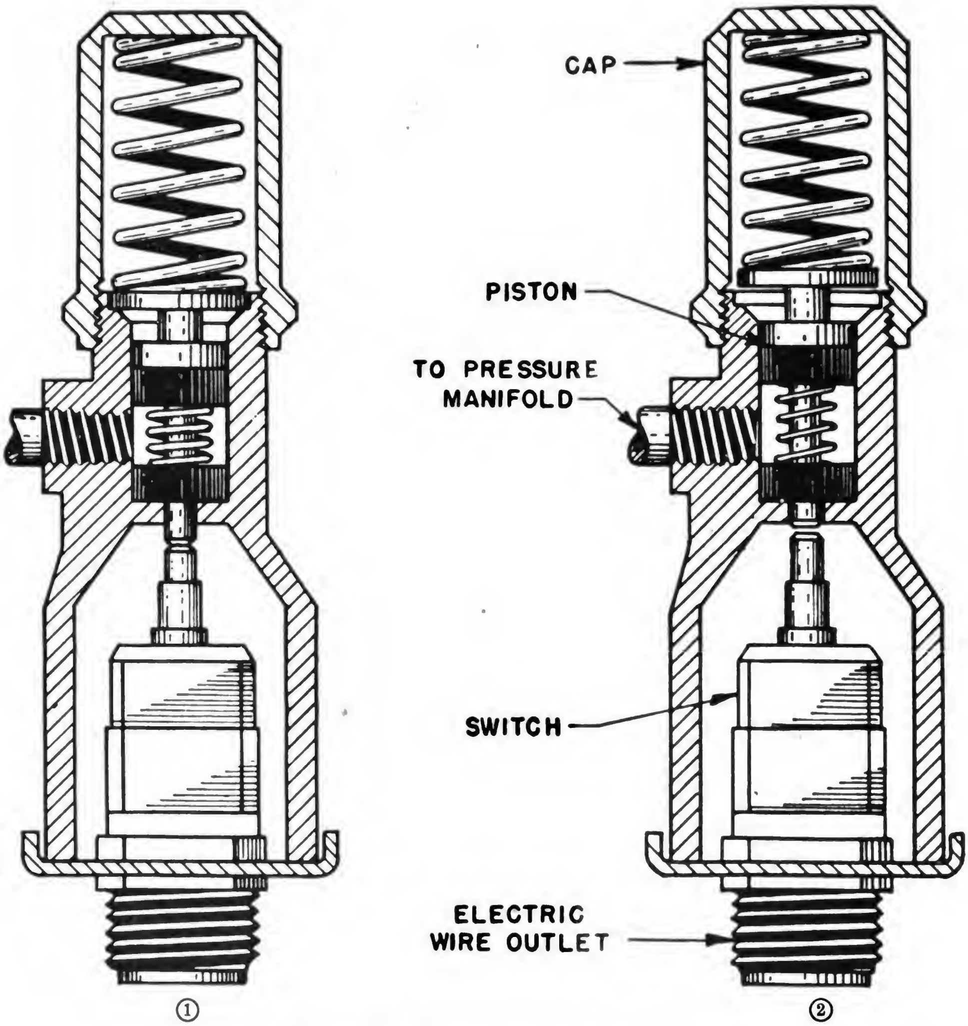
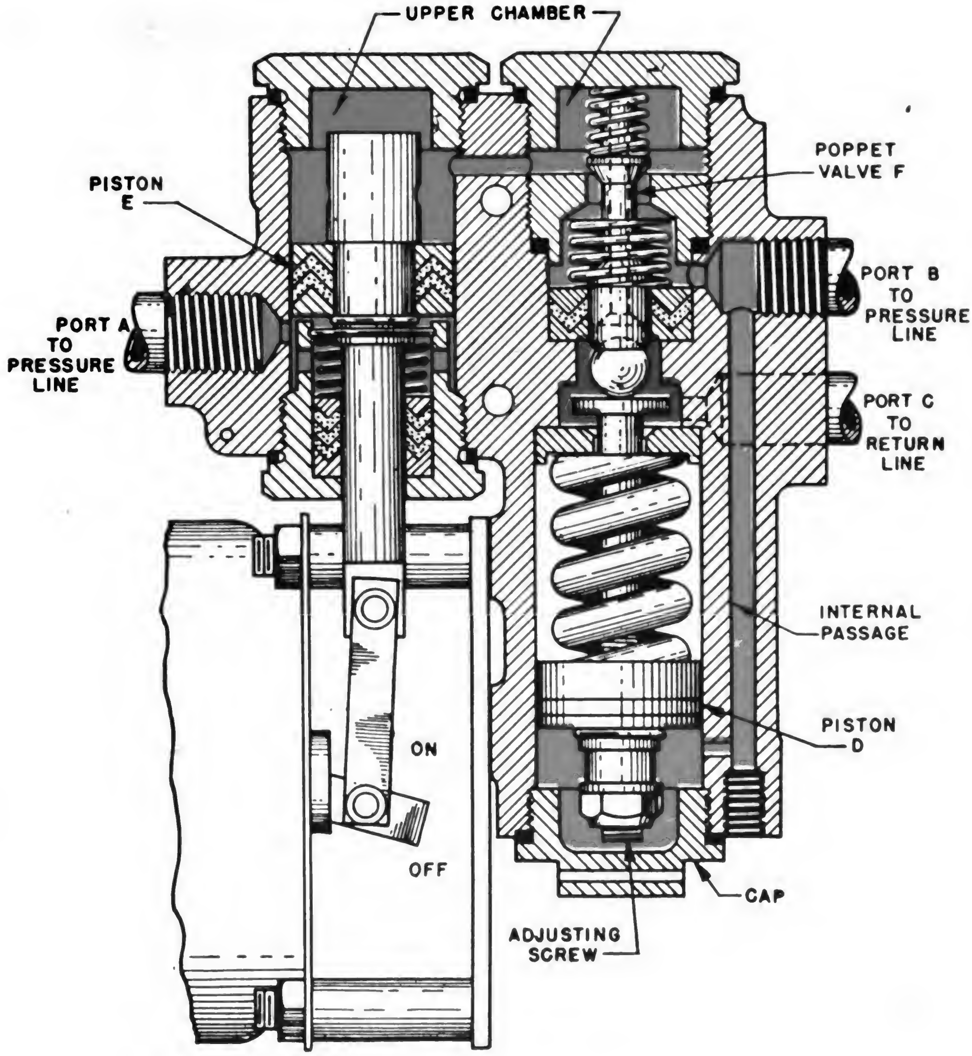


Figure 50. Pressure warning switch.

and a hollow poppet valve, *F*. Piston *D* is held down by a spring, but is so placed that the end of its rod will move the ball up and close the passage in the hollow poppet when pressure becomes great enough. Any further increase in pressure will cause piston *D* to raise poppet *F* from its seat, Piston *E* is attached to the switch by a piston rod. Upward movement of piston *E* turns the switch on, and downward movement turns the switch off.

(3) *Operation.* This unit is shown in the OFF position in figure 51. System pressure acting through port *B* and the internal passage holds piston *D* up. When the piston *D* is in this position, the opening in the hollow poppet is closed by the ball and the poppet valve is held off its seat. When the poppet valve is off its seat, the upper chamber is connected to system pressure, and the pressure acting on the top of piston *E* is the same as the pressure acting on the bottom of piston *E*. Since the area of the top of piston *E* is greater than the area of the bottom (because of the area of the piston rod), the force holding the piston down will be greater than the force push-



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 51. Pressure switch.

ing it up. The switch will therefore remain in the OFF position until system pressure is reduced. Now, as system pressure drops, the large spring forces piston *D* down and allows the poppet valve to seat. Any further decrease in pressure will allow the ball to move away from the opening in the hollow poppet. This action will connect the upper chamber to the return line through the hollow poppet and the pressure in the upper chamber will drop to zero. The instant this occurs, the force holding piston *E* down will drop to zero and system pressure acting on the bottom of piston *E* will move it up and snap on the switch. The pump will then be started, and pressure in the system will increase until piston *D* is again moved upward far enough to unseat the poppet.

39. PRESSURE-GAUGE SNUBBER. a. Purpose. The irregularity of the impulses applied to the system by some engine-driven power pumps causes the pressure gauge pointer to oscillate violently. This is disconcerting to the observer and makes it difficult to obtain an accurate reading. A pressure gauge snubber is sometimes installed in the line to the pressure gauge. The purpose of this unit is to dampen the oscillations and thus give a steady reading.

b. Description and operation. The unit shown in figure 52 consists of a two-port housing containing an orifice with a floating plunger in it. This plunger is free to bounce up and down, but because of its inertia, it

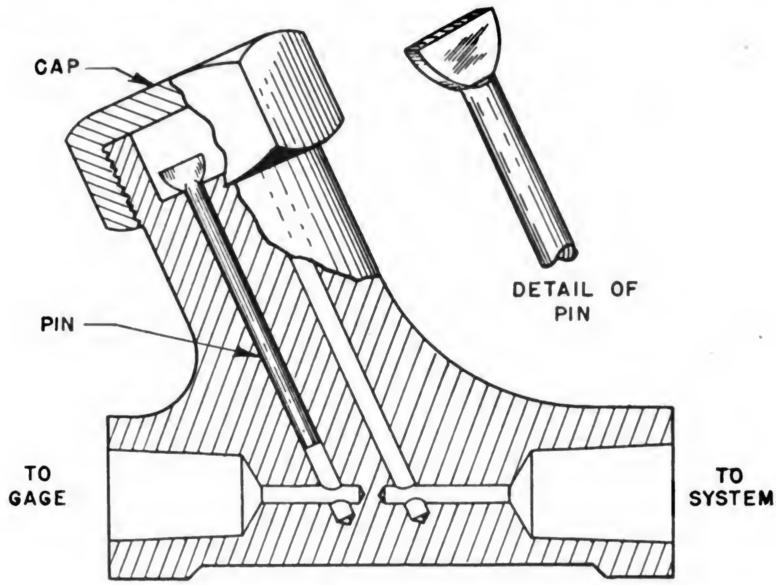


Figure 52. Pressure-gauge snubber.

tends to remain stationary. The weight of the pin thus opposes the pressure surges in the oil and "cancels out" most of them before they reach the pressure gauge. This reduction in surges results in a steadier pointer indication and therefore a more accurate reading.

SECTION VI

BRAKE ACTUATING SYSTEMS

40. GENERAL. a. Purpose. An airplane brake actuating system is designed to permit application of the brakes for landing, taxying, and parking. Provision is made for applying either one or both brakes the desired amount by operation of the foot pedal.

b. Types and uses. Brake actuating systems may be mechanically, hydraulically, or pneumatically operated.

(1) Mechanical type brakes are now used only on older and lighter weight airplanes. This type of system employs cables, pulleys, and bell cranks to connect the foot pedal to the brake shoe.

(2) A hydraulic brake system may be a part of the main hydraulic system or it may be an entirely independent system. Independent or master cylinder brake systems are used on most of the comparatively light airplanes. Larger airplanes usually employ a power-brake control-valve system which is a part of the main hydraulic system.

(3) Pneumatic brake systems are used for emergency operation.

41. MASTER-CYLINDER BRAKE SYSTEMS. a. Description. Figure 53 is a drawing of a typical master cylinder brake system. The following units are incorporated in this system:

(1) *Master cylinder.* The master cylinder is the energizing unit of the brake system. It is a manually operated, single-action, reciprocating pump which builds up fluid pressure in the system. There is one master cylinder for each main landing-gear wheel.

(2) *Reservoir.* The purpose of the reservoir is to make available an adequate supply of fluid to compensate for slight leaks in the connecting lines. The reservoir may be a separate unit or an integral part of the master cylinder. As the reservoir is vented to the atmosphere to provide gravity feed to the pressure chamber, the correct oil level must be maintained or air will be introduced into the system.

(3) *Mechanical linkage.* A linkage made up of rods and levers connects the brake pedal to the master cylinder. As the brake pedal is moved forward, the linkage causes the master cylinder piston to move. When the foot pressure is removed, the pedal is returned to the OFF position by the action of springs in the system. Although the brake pedals are a part of the

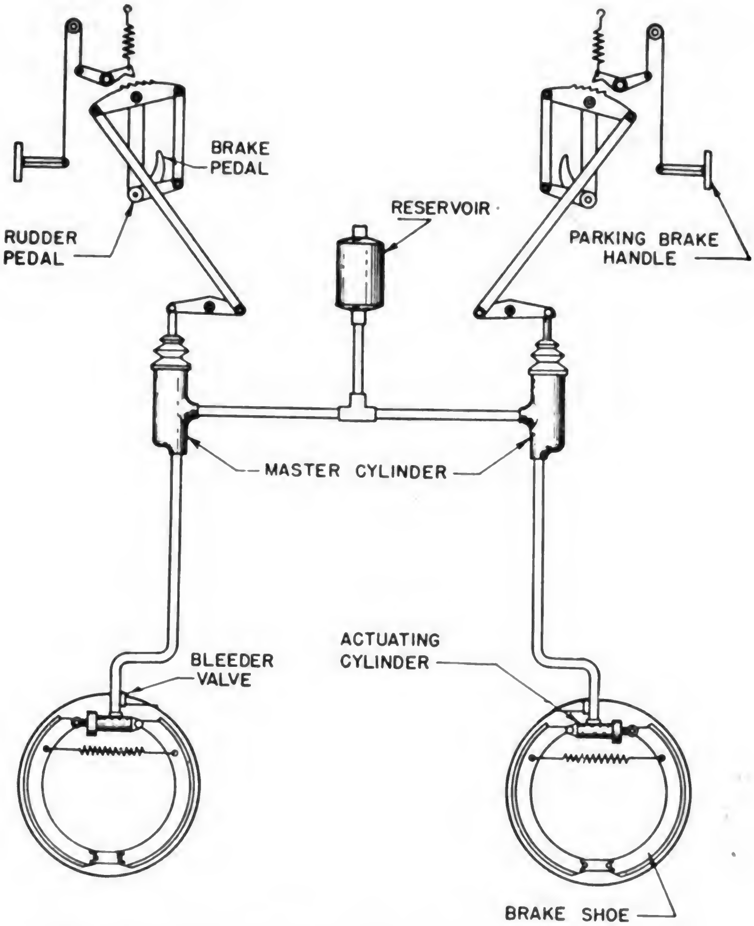


Figure 53. Typical master cylinder hydraulic brake system.

rudder pedal assembly, the brakes can be operated independently of the rudder or vice versa; however, the two can be operated simultaneously if so desired.

(4) *Fluid lines.* Fluid lines may be flexible or a combination of rigid and flexible tubing.

(5) *Brake actuating cylinders.* These units are located in the brake assembly. When pressure from the master cylinders is transmitted to them, they cause the brake shoes to press against the brake drum.

(6) *Parking brake mechanism.* Each hydraulic brake system includes a parking brake mechanism with a control accessible to the pilot. The brakes are locked in the ON position by depressing the brake pedals and then pulling the parking brake lever. They are released by depressing the brake pedals. This action will (depending on the type of master cylinder) either unload the ratchet type parking lock or build up sufficient pressure to unseat the parking valve. When the pedals are released, the master cylinder pistons return to the OFF position.

b. Operation. (1) The principle of operation of the various types of master cylinder brake systems are fundamentally the same, the difference

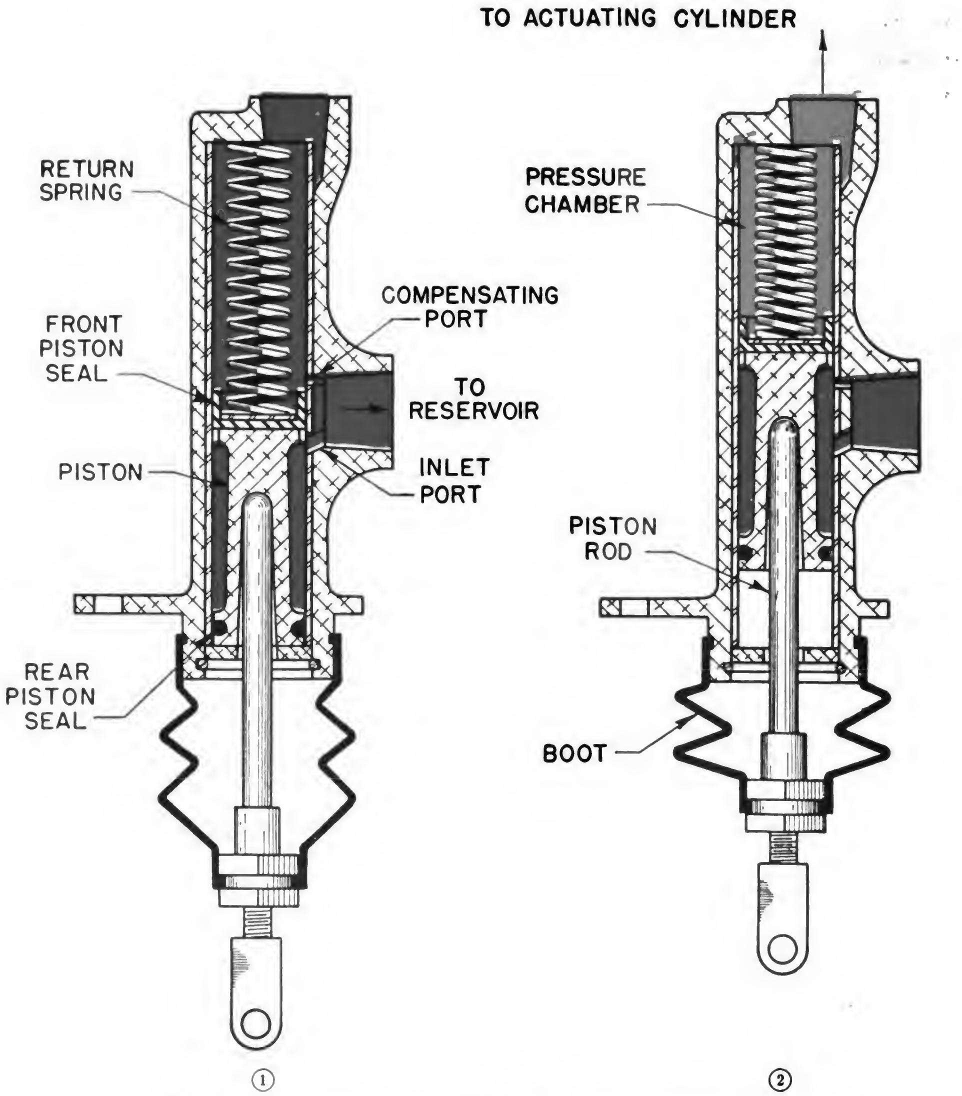
existing in the structural details of the various units rather than in their operation. Each brake pedal operates an individual master cylinder as shown in figure 53, thus allowing the pilot to operate the brakes individually or simultaneously. Brake fluid flows from the reservoir by gravity to the pressure chamber of the master cylinder and completely fills the system. When force is applied to the brake pedals, the pistons are moved in the master cylinders, causing the fluid to flow through the lines to the actuating cylinders. Since the fluid is restricted to the system, its pressure increases with increased force on the pedals. On the return stroke, the various return springs acting against their respective pistons force the fluid back to the master cylinder.

(2) To prevent the application of the brakes from the OFF position by the pressure developed by the thermal expansion of the fluid, the master cylinder is equipped with a compensating port or valve which allows the excess fluid to flow from the pressure chamber back to the reservoir. A slight movement of the piston closes the compensating valve or port and permits the build-up of pressure.

c. Master cylinders. There are four different types of master cylinders in general use. These are:

(1) *Goodyear.* Fluid enters the Goodyear master cylinder from the external reservoir through the inlet and compensating ports as shown in figure 54①. Application of the brake forces the piston up (fig. 54②), blocking the compensating port and building up pressure in the pressure chamber. This pressure is transmitted to the brake-actuating cylinder. When the force is removed from the pedal, the piston is returned to the OFF position by the action of the return spring. Any change in the volume of the fluid due to temperature changes while in the OFF position is compensated by the passage of fluid through the compensating port. Locking of the brakes in the ON position for parking is accomplished by a ratchet type lock which is built into the mechanical linkage between the master cylinder and the foot pedal. Any change in the volume of the fluid due to expansion while the parking brake is on is taken care of by a spring incorporated in the linkage. The brakes are unlocked by applying sufficient pressure on the brake pedals to unload the ratchet.

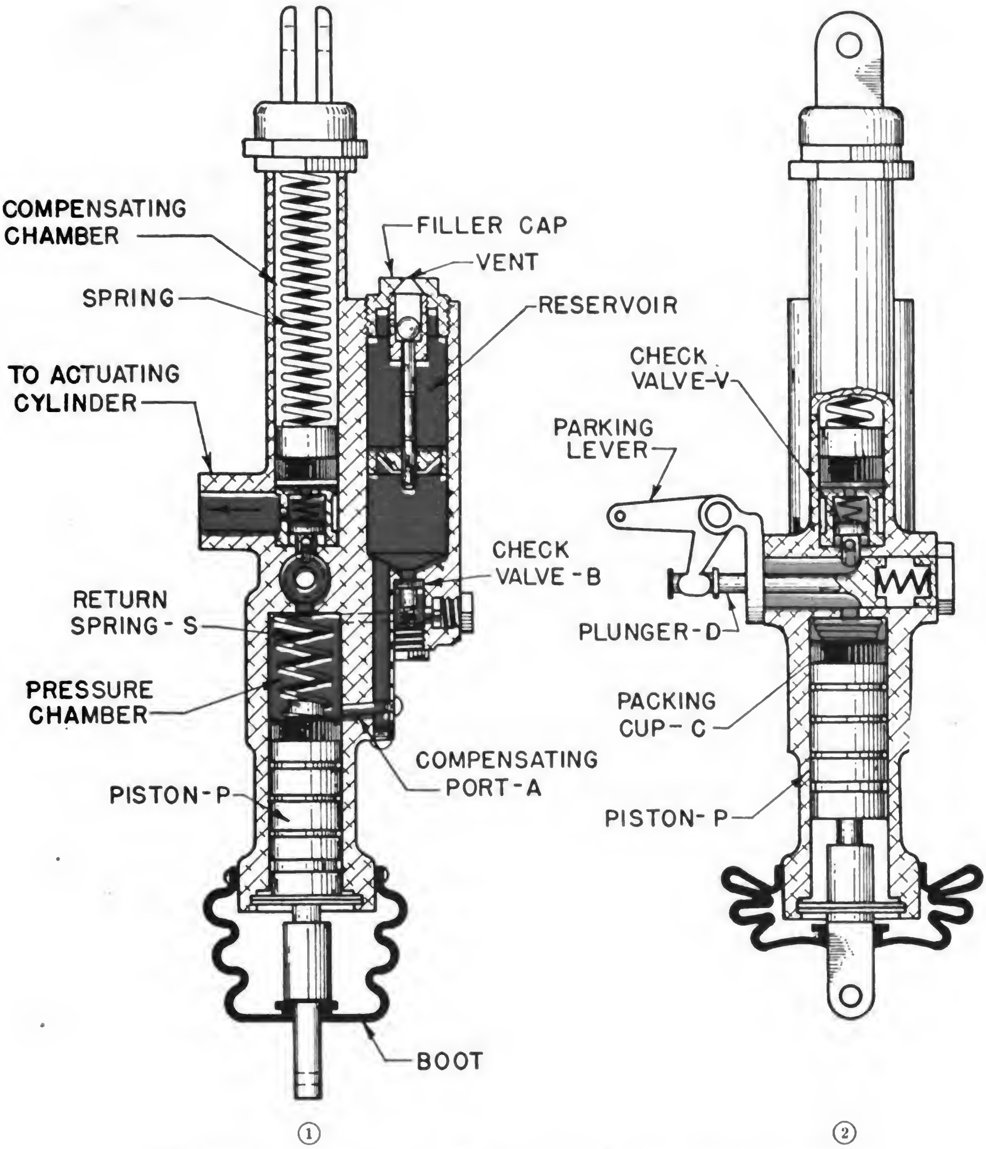
(2) *Bendix.* The Bendix master cylinder incorporates a reservoir, a pressure chamber, and a compensating chamber in the same unit. The reservoir is vented to the atmosphere through a small ball check valve in the filler cap which prevents the loss of fluid when the airplane is inverted in flight. Fluid enters the pressure chamber (fig. 55①) from the reservoir through the compensating port and the check valve *B*. When pressure is applied to the foot pedal, the piston is moved upward (fig. 55②), forcing the fluid through the check valve *V* and into the fluid line to the actuating cylinder. Before pressure can be built up in the system, the piston must move beyond the compensating port. Hence there is a cushioning effect which prevents a violent



● *Fluid under pressure.* ● ***Fluid under atmospheric pressure.***

Figure 54. Goodyear master cylinder.

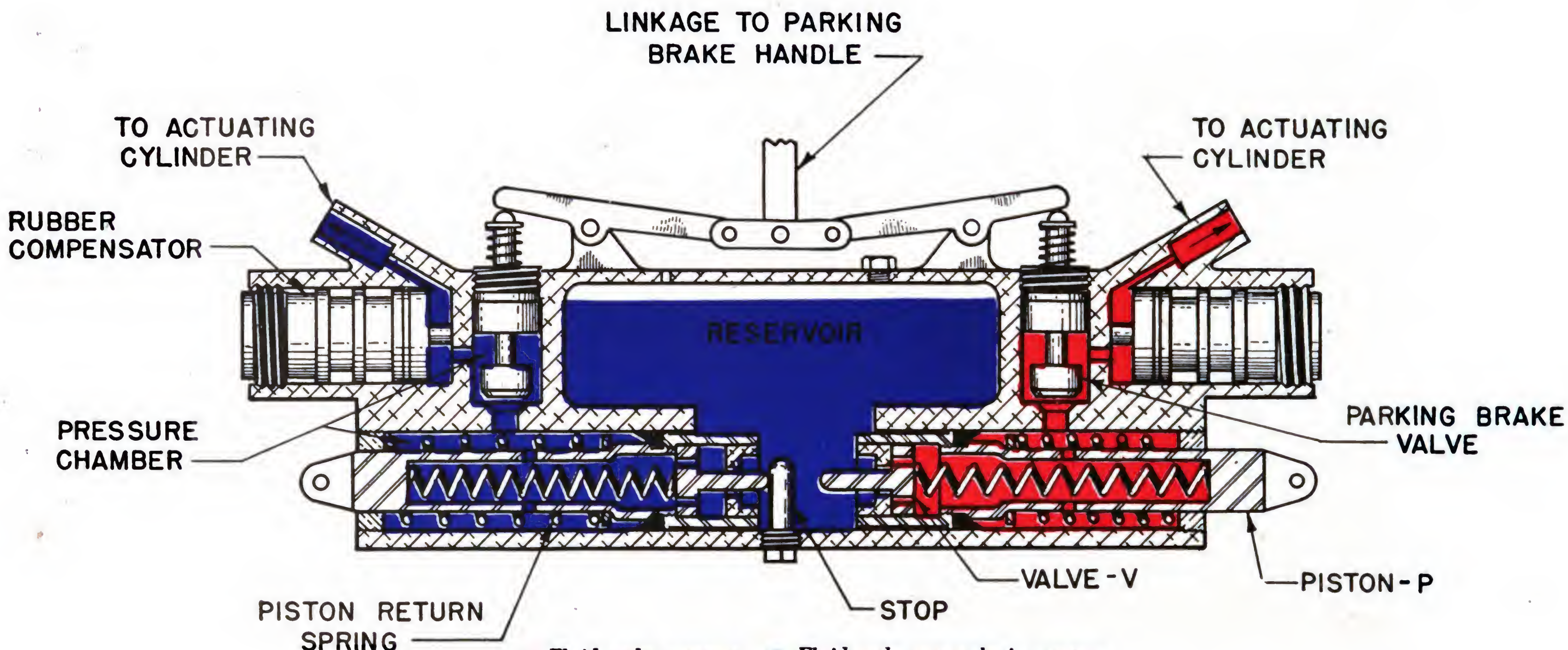
locking of the brakes if they are applied too quickly. When foot pressure on the pedal is removed, the return spring forces the piston to the OFF position. When there is an insufficient amount of fluid in the system, because of leakage, an additional amount will flow in through the check valve *B* on the down stroke. Compensation for change in fluid volume due to temperature variation while the brakes are in the OFF position is accomplished by the compensating port, which allows fluid to flow to or from the pressure chamber as required. Locking of the brakes in the ON position for parking is accomplished by pulling the parking brake lever while the brakes are being applied. This action forces the plunger *D* inward, compressing the plunger spring and allowing the valve *V* to seat. This valve traps oil under pressure in the bottom of the compensating chamber and in the brake line. As the



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 55. Bendix master cylinder.

compensating spring is partially compressed, it will maintain pressure in the brake system. When there is a change of volume due to thermal effects while the brakes are parked, the compensating spring either contracts or expands, thus maintaining constant pressure. Release of the parking brakes is accomplished by unseating the valve *V* with fluid pressure generated in the pressure chamber by the action of the brake pedal. This pressure must be greater than that in the compensating chamber in order to unseat the valve. As the valve *V* moves up, the plunger is forced out by its spring, thus holding the valve open and allowing the fluid to flow back into the pressure chamber as the force on the brake pedal is released.



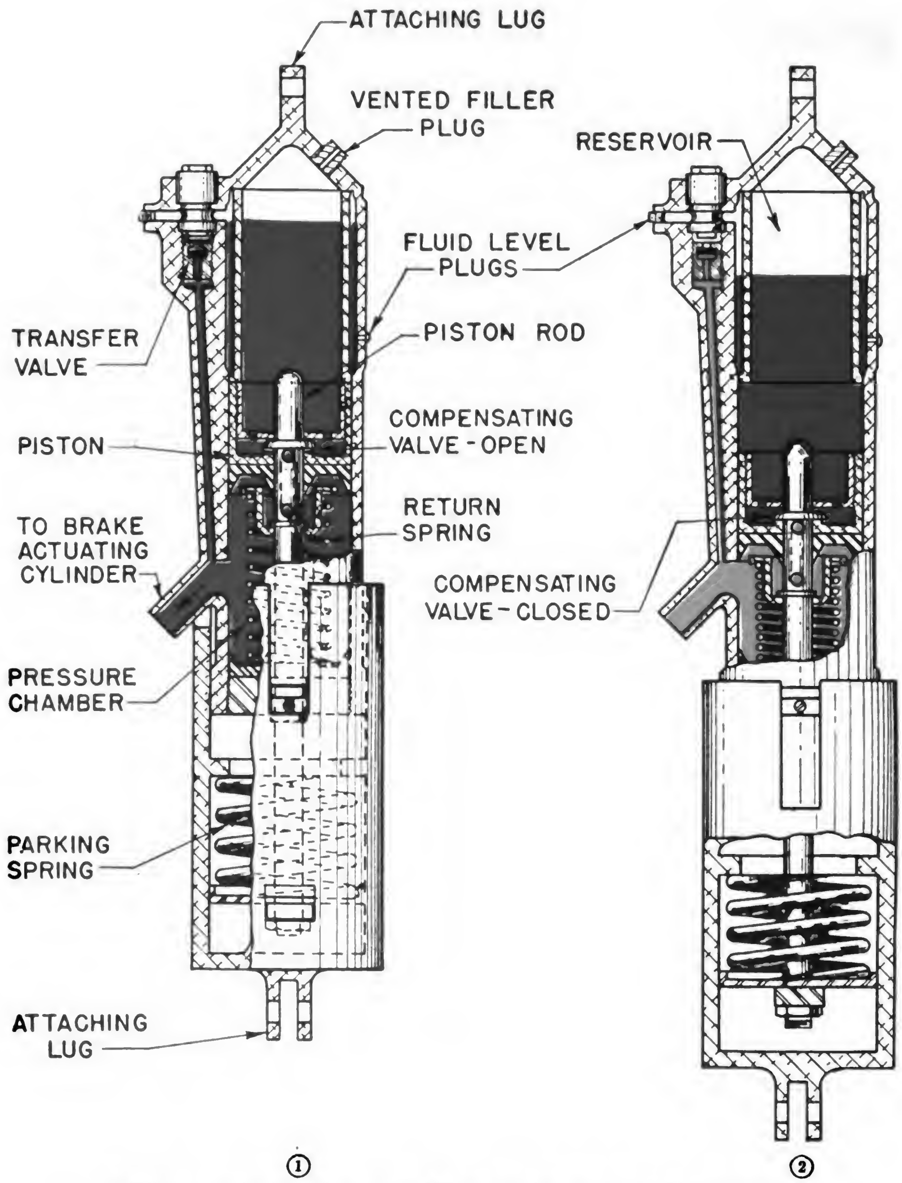
Fluid under pressure. *Fluid under atmospheric pressure.*

Figure 56. North American master cylinder.

(3) *North American.* The North American unit utilizes a single casting for housing the reservoir and two cylinders as shown in figure 56. The right half of figure 56 illustrates the ON position, the left half illustrates the OFF position. Application of force to the brake pedal moves the piston *P* to the right. This action closes the valve *V* and builds up pressure in the system. The piston return spring moves the piston to the OFF position when the force is removed from the foot pedal. As the stem of the valve *V* strikes the stop, the valve is opened and fluid can enter from the reservoir. Locking of the brakes in the ON, or parked, position is accomplished by first applying the brakes and then trapping the fluid under pressure in the system by pulling on the parking brake handle. This action closes the parking brake valves and permits the piston to return to the OFF position without releasing the brakes. A rubber compensator prevents damage due to expansion of the fluid. The brakes may be released from the parked position by applying sufficient pressure to the pedals to unseat the parking brake valve.

(4) *Warner.* Reservoir, pressure chamber, compensating valve, transfer valve, and parking spring and ratchet lock in one assembly are incorporated in the Warner unit. Force applied to the brake pedal is carried by a mechanical linkage to the bottom attaching lug of the master cylinder. (See fig. 57.) As the piston is moved downward (fig. 57②) the compensating valve is closed and pressure is reproduced in the pressure chamber. This pressure cannot escape through the closed transfer valve. The return spring moves the piston to the OFF position when pressure is released from the pedal. Increases or decreases in the volume of fluid when the brakes are OFF are compensated by the compensating valve, which permits the flow of fluid between the reservoir and the pressure chamber. Locking of the brakes in the ON or parked position is accomplished by engaging a ratchet which locks the piston in the ON position. This action results in the compression of the parking spring. Increases or decreases in the volume of the fluid due to temperature variation are compensated by this spring, which extends with a decrease of volume and compresses with an increase in volume. The purpose of the transfer valve is to allow free flow of oil from the reservoir to the brake line when the brakes are being bled. This valve is kept closed at all other times.

42. POWER BRAKE CONTROL VALVE SYSTEMS. a. General. Pressure from the main hydraulic system is utilized by the power brake control valve system to actuate the brakes. Since normal system pressure exceeds the maximum pressure required for actuating the brakes, a device is incorporated in the brake system to control the pressure transmitted from the pressure manifold to the brake actuating cylinder. Such a device is called a "power brake control valve." A brake de-booster is sometimes used with a power brake control valve. This unit further reduces the pressure from the power brake control valve so that smoother brake application can be obtained.

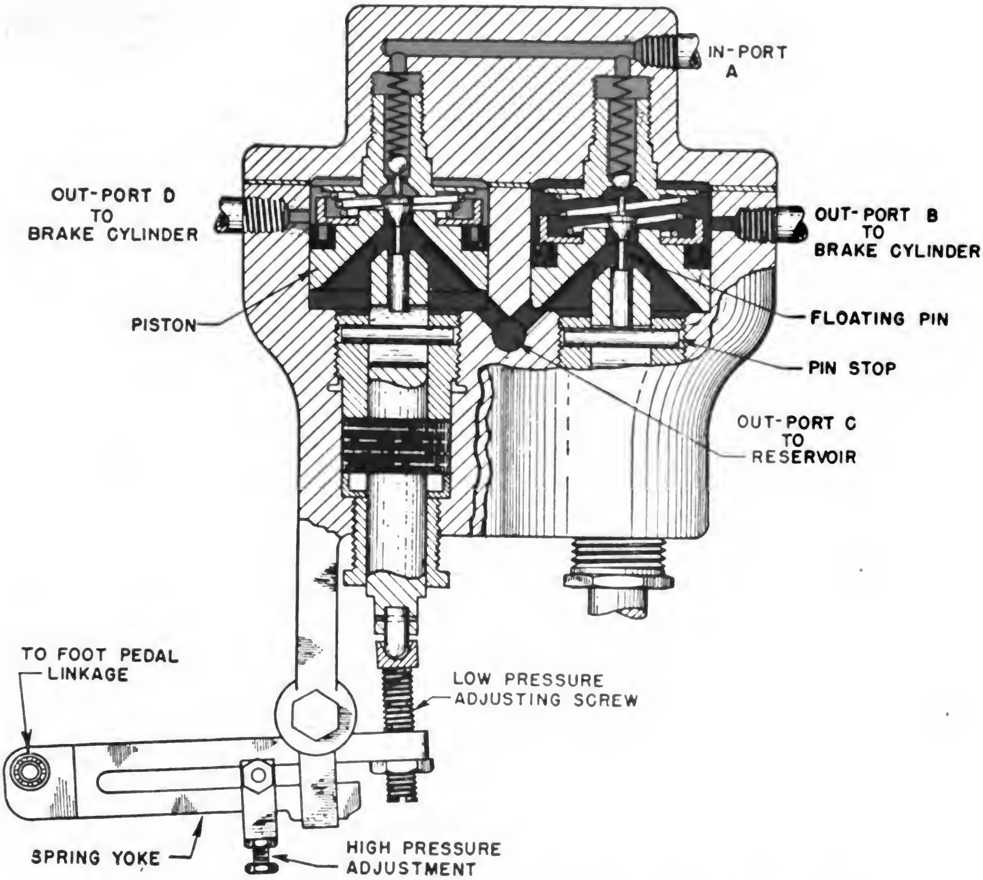


● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 57. Warner master cylinder.

b. Power brake control valve. A controlled amount of pressure is metered by the power brake control valve from the main hydraulic system to the brake system. The amount of pressure admitted to the brake system depends on the force applied to the foot pedal. Two typical types of power control valves will be discussed. They are the external spring type and the internal spring type. Both types may be compound units containing two control valves built into the same housing. Each control valve is independent of the other and supplies pressure for one set of wheel brakes.

(1) *External spring type.* The power brake control valve shown in figure 58 consists of a four-port housing, two control valve assemblies, and two



● *Fluid under pressure.* ● *Fluid under atmospheric pressure.*

Figure 58. External spring type power brake control valve

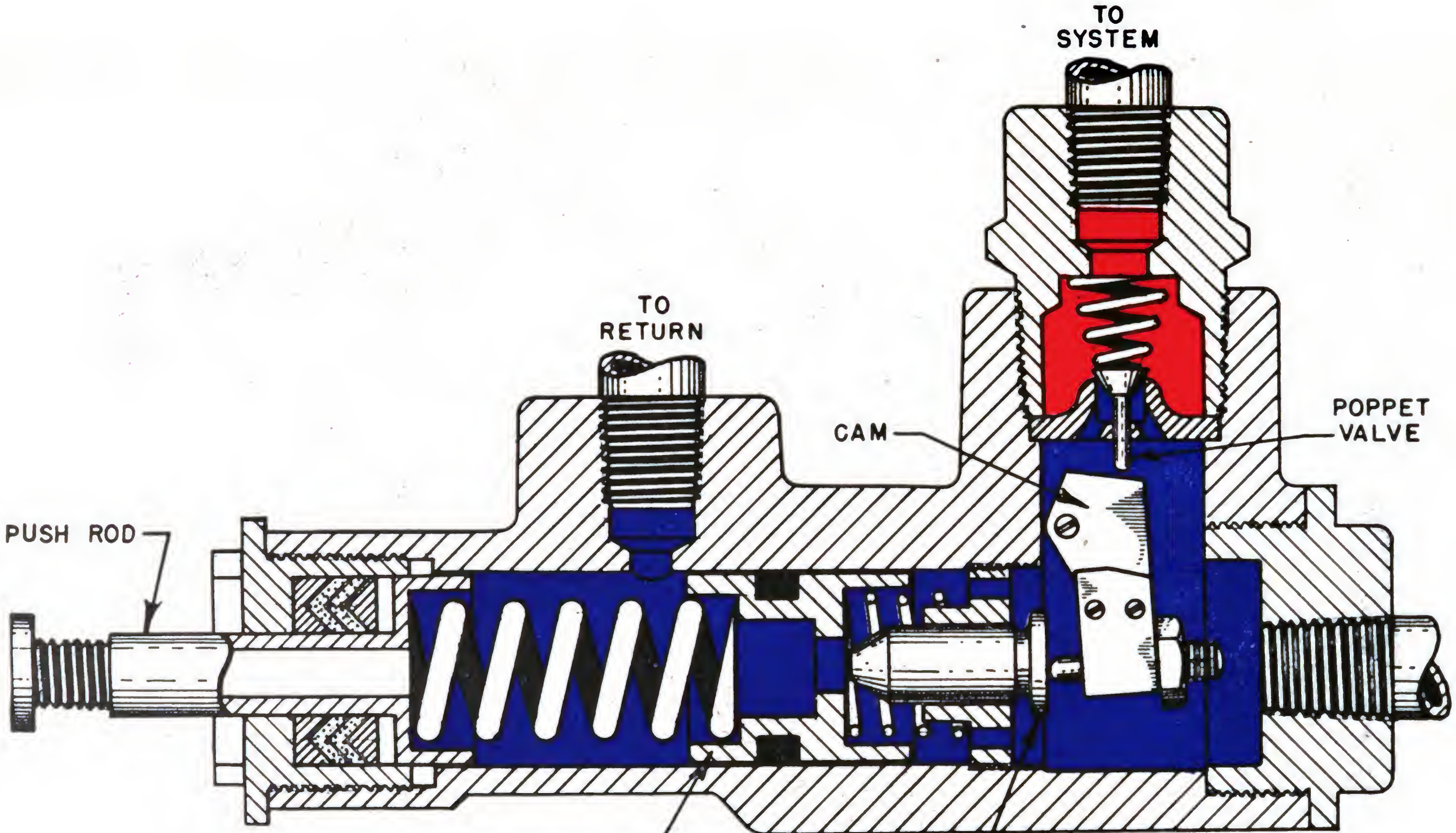
external spring yokes. The control valve assembly consists of a check valve and a piston containing a floating pin. The rod attached to the piston extends outside the housing and contacts one end of the spring yoke. When the unit is in the position shown in the right side of figure 58, the check valve is on its seat and prevents oil under pressure in the main hydraulic system from reaching the brake line. The brake line is connected to the return through the drilled passages in the piston. When the right foot pedal is depressed, the right spring yoke will be rotated about its pivot by the linkage connecting the foot pedal and the yoke. The first part of this rotation moves the piston up far enough to allow the shoulders on the pin to seat on the piston and close the return passages. Any further movement of the piston will move the pin up and unseat the check valve. This position is shown in the left side of figure 58. Oil under pressure from the main system flows through inport *A*, by the check valve, and out of port *D* to the right wheel break assembly. Pressure acting on top of the piston produces a force which tends to move the piston down. When this pressure becomes great enough to bend the spring yoke, the piston and pin will move down

and allow the check valve to seat. When this happens, no more pressure can reach the brake line. The amount of pressure which may reach the brake line is determined by the amount the spring yoke must be bent to allow the check valve to seat, which is determined by the amount the spring yoke is rotated. As the spring yoke is rotated by movement of the foot pedal, the amount of pressure admitted to the brake lines is determined by the distance the foot pedal is depressed. When the foot pedal is released, the piston and pin will be moved down by pressure on the top of the piston. The piston moves down a short distance after the pin strikes the pin stop. This movement separates the shoulder on the pin and piston and opens the drilled passages in the piston. Oil is then free to flow to the bottom of the unit and out of port *C* to the return, and the brakes are released.

(2) *Internal spring type.* The power brake control valve shown in figure 59 consists of a three-port housing, a push rod, a spring, a slide valve, a bullet type check valve, a cam, and a poppet valve. When the unit is in the position shown in figure 59, pressure from the system is stopped at the seated poppet valve. When the foot pedal is depressed, the push rod is moved into the housing by the actuating lever. This action compresses the spring and moves the slide valve to the right. On the first part of the movement, the bullet valve closes the escape passage in the center of the slide valve. As the slide valve continues to move to the right, the bullet valve is moved with it. This motion rotates the cam about its pivot and opens the poppet valve in the pressure port. Oil under pressure from the main system is then free to flow around the poppet valve and out of the port to the brake line. Pressure in the brake line acts on the face of the slide valve and the bullet valve. As this pressure increases, it forces the slide valve and the bullet valve to the left against the force of the spring. As the bullet valve moves to the left, the poppet valve closes and prevents additional pressure from reaching the brake line. Thus the pressure in the brake line is governed by the amount the spring must be compressed to allow the poppet valve to seat. This amount is determined by the distance the plunger is moved to the right by the brake pedal linkage. Thus the pressure metered to the brakes is directly proportional to the distance the foot pedal is depressed, and any desired pressure up to the maximum for which the unit is set may be metered to the brake system. This maximum is governed by the thrust of the push rod, the strength of the spring, and the adjustment of the inlet valve adjusting screws.

c. **Brake de-booster valve.** (1) *Purposes.* The two purposes of the brake de-booster valve are: to reduce pressure from the brake control valve pressure to that required by the brake, and to insure rapid release of the brake.

(2) *Description.* The brake de-booster valve consists essentially of a cylinder barrel which is fitted with a cylinder head on each end. These heads provide connections for the brake control valve and the brake lines. Inside



Fluid under pressure. *Fluid under atmospheric pressure.*

Figure 59. Internal spring type power brake control valve.

the cylinder are a piston guide sleeve and a spring loaded piston. This piston divides the cylinder into a small volume, high-pressure chamber (connected to the brake control valve through port *A*, figure 60) and a larger volume, low-pressure chamber (connected to the brake lines through port *B*). Built into the center of the piston head is a ball type compensating valve.

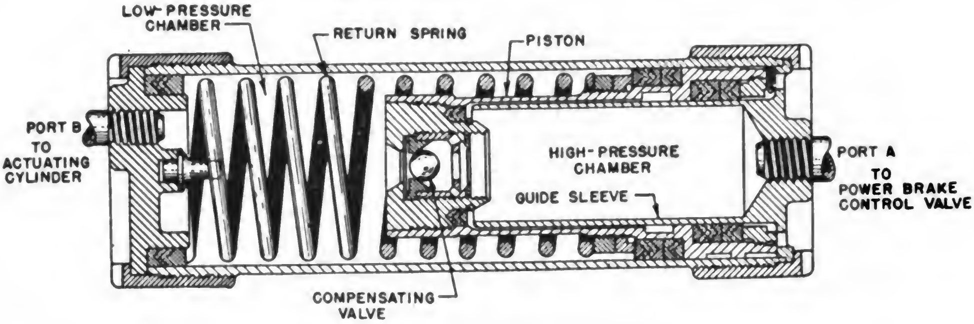


Figure 60. Brake de-booster valve.

(3) *Operation.* Oil pressure from the brake control valve enters port *A* and acts on the inside of the piston, moving the piston toward the left. As the piston moves into the large volume chamber, the return spring is compressed and oil is forced out of port *B* into the brake lines. The pressure in the large volume chamber is less than that in the small volume chamber for two reasons; pressure acting on the inside of the piston must compress the strong piston return spring before the piston can be moved to the left; and any pressure applied to the small inside area will be "spread over" the larger outside area. The pressure created in the large volume chamber will therefore be less than the pressure applied to the small volume chamber. Thus the unit "de-boosts" or reduces the pressure, with the result that smooth brake application can be obtained with maximum system pressure applied to the brake control valve. The instant pressure from the brake control valve is diminished or released, the piston return spring moves the piston to the right. This action immediately reduces the pressure in the low-pressure chamber and the brakes are unloaded a corresponding amount. With the brakes applied, the piston normally moves nearly the full length of the cylinder. If there is leakage from the brake system, the piston will move toward the left until the fixed pin in the outlet end cylinder head opens the compensating valve. Oil then flows into the low-pressure chamber until its fluid volume increases sufficiently to move the piston away from the pin and allows the compensating valve to close. Because of the larger area of the outside of the piston, pressure applied to the brake when the compensating valve is open cannot exceed the maximum value normally developed by the piston during its stroke.

43. EMERGENCY PNEUMATIC-BRAKE SYSTEMS. a. Purpose. In case of failure of the hydraulic brake system, the emergency pneumatic

brake system is used. The brakes are energized with compressed air when the control valve is opened manually.

b. Description. The pneumatic brake system (fig. 61) consists of the following units:

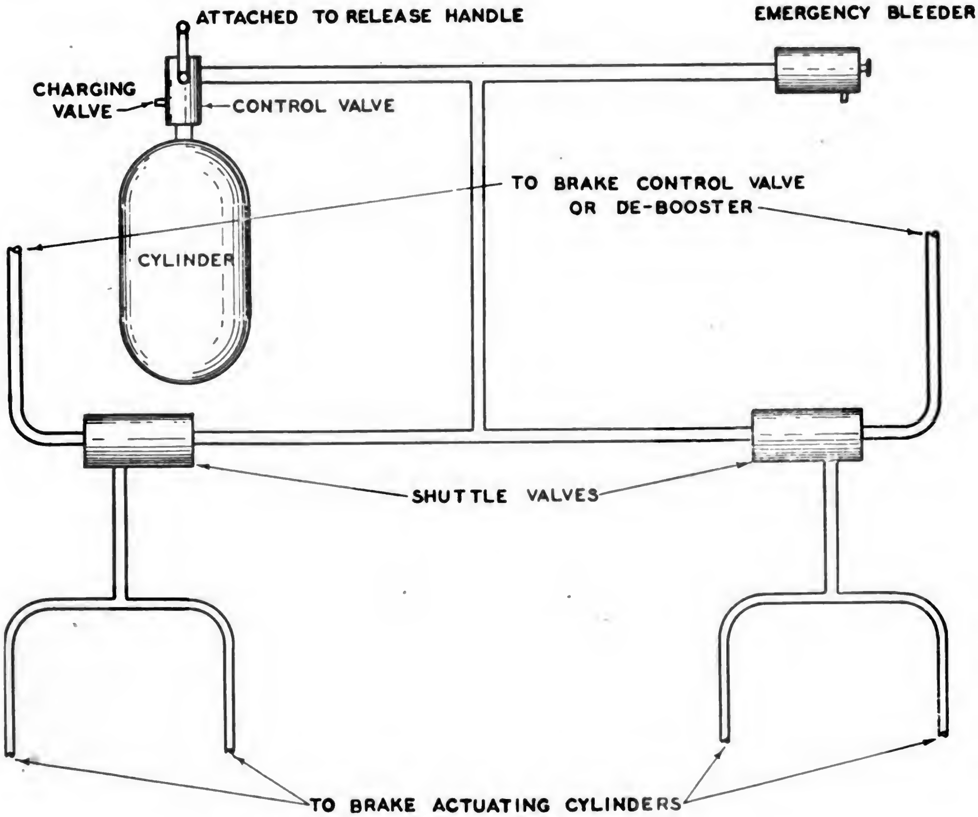


Figure 61. Emergency pneumatic brake system.

(1) A high-pressure cylinder which is charged with compressed air.

(2) A control or release valve which is mounted on the cylinder. The release handle, which is attached to the control valve, must be within easy reach of pilot and copilot.

(3) Shuttle valves which direct the compressed air to the brake actuating cylinders, and at the same time close the port to the main hydraulic system to prevent loss of pressure.

(4) Connecting tubing and fittings.

(5) An emergency bleeder valve (in some systems), the purpose of which is to release the brakes by allowing the compressed air to escape to the atmosphere.

c. Operation. To apply the brakes, it is necessary only to open the control valve. When this valve is opened, compressed air from the cylinder enters the brake lines. The piston in the shuttle valve closes the normal operating port and allows air to enter the brake actuating cylinder and apply the brakes. In some installations the amount of braking can be varied by

the control valve. In other installations, opening the control valve releases full cylinder pressure into the lines.

(1) To release the brakes, the control valve is closed and the emergency bleeder valve opened. Some systems have both of these valves incorporated in one unit to simplify this operation.

(2) After each use of the pneumatic system, the hydraulic system must be bled, the cylinder recharged, and the control handle safetied in the OFF position. Since use of this system may subject the tires to abnormal wear, the tires should be carefully inspected each time the system is used.

44. INSPECTION AND MAINTENANCE OF BRAKE SYSTEMS.

a. The operation of airplane brake systems must be faultless at all times. To assure this, inspections must be performed at regular intervals. Maintenance work which might be indicated as a result of these inspections should be performed promptly and carefully.

b. Inspection. Brake systems should be inspected periodically for:

(1) *Leaks.* All lines are inspected with the system under full operating pressure. Loose fittings must be tightened with the pressure OFF. All flexible lines should be carefully checked for swelling, cracking, and soft spots, and replaced if they show signs of deterioration. If leaks are found at the master cylinder or actuating cylinder, packing nuts may be tightened. Care should be exercised in tightening these nuts to prevent binding of the rods.

(2) *Presence of air in system.* Air in the system is indicated by "spongy" action of the foot pedals. If air is found in the system, it should be removed by bleeding.

(3) *Operation.* If the general operation of the system is unsatisfactory, some unit may require repair or replacement. Check all linkages carefully before removing any unit. Scored cylinders, bent piston rods, or other unserviceable conditions are sufficient justification for replacement. The replacement of cups, seals, or gaskets may constitute a satisfactory repair.

(4) *Fluid level.* The proper oil level should be maintained in the master cylinder reservoir at all times to prevent brake failure or the introduction of air into the system.

c. General bleeding procedure. Whenever hydraulic brake lines are disconnected, air will be admitted to the system. This condition may develop also if there is insufficient oil in the reservoir of a master cylinder system. If air enters the system in any way, it must be removed by bleeding. Three general methods of bleeding master cylinder brake systems and one general method of bleeding power brake control valve systems will be discussed. It is to be remembered that these are general methods. Each installation will have its own problems. The handbook of instructions should be consulted before bleeding a particular type of system.

(1) Master cylinder hydraulic brake systems may be bled by pumping fluid through the system, the master cylinder being used as a pump. The

special equipment illustrated in figure 62 is required for this method. The free end of the filler can hose is attached to the reservoir filler plug opening. The can is then partially filled with the same hydraulic fluid that is being

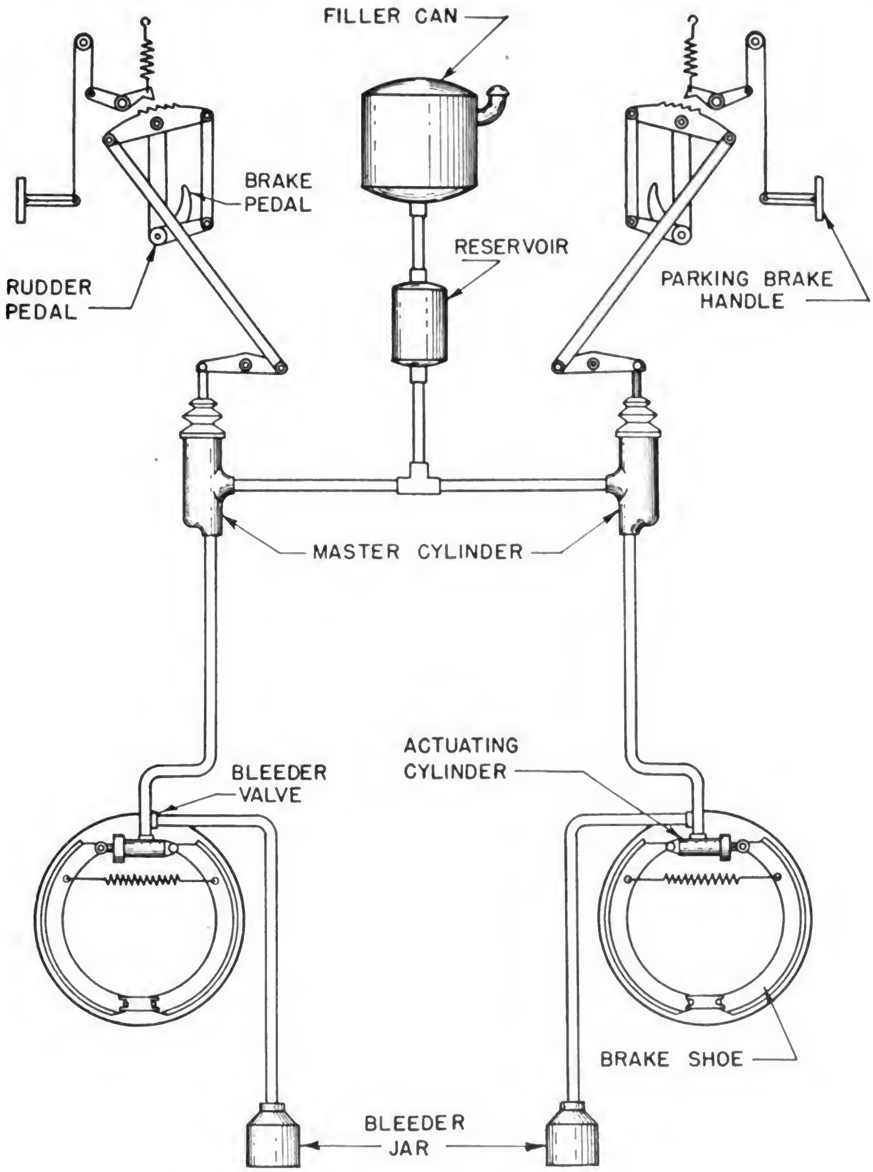


Figure 62. Hydraulic-brake system bleeding.

used in the master cylinder. A hose is attached to the actuating cylinder bleeder valve and the free end submerged in hydraulic fluid in a glass jar. The brake pedal is then operated back and forth. During this operation, the bleeder valve is kept open during the rapid down strokes of the brake pedal and closed before the brake pedal is allowed to return slowly. Operation of the pedal is continued until air bubbles no longer appear in the glass jar. This may require pumping one or more pints of fluid through the sys-

tem. The bleeder valve is then closed tightly, and the hose is removed on completion of the bleeding operation. The fluid level in the reservoir should be checked and brought to the desired level.

(2) Bleeding of master cylinder hydraulic brake systems may be accomplished by forcing fluid into the system through the actuating cylinder bleeder valve. Figure 63 illustrates typical equipment for this operation. The reservoir filler plug is removed, a nipple is inserted, and a hose is attached with the free end leading into a clean can. The actuating cylinder bleeder

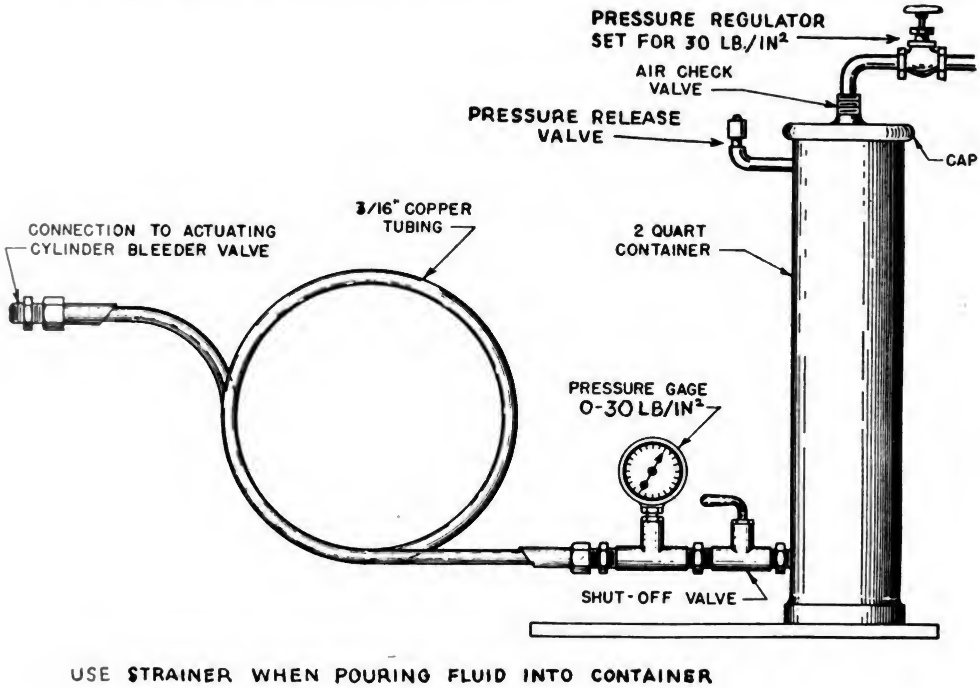


Figure 63. Pressure-bleeding equipment.

port is opened and the oil line from the container is attached. This oil line should incorporate a shut-off valve and a pressure gauge. The fluid in the filler container should be put under a pressure of from 6 to 10 pounds per square inch by adding compressed air. With the brakes released, the shut-off valve in the line leading to the brake actuating cylinder should be slowly opened, allowing fluid to flow into the cylinder. Do not let the pressure in the actuating cylinder exceed a minimum necessary to cause fluid flow through the system. Allow fluid to flow back through pressure tank by gravity to remove air bubbles from the brake. As soon as fluid runs out of the hose connection from the reservoir filler plug, the shut-off valve should be closed. The bleeder valve at the actuating cylinder may then be closed and the filling equipment removed. The fluid level in the reservoir should then be checked and brought to the desired level.

(3) In a few cases, bleeding of master cylinder hydraulic brake systems may be accomplished also by air pressure applied through an air valve in

the top of the reservoir. Compressed air is added to the reservoir until a pressure of approximately 6 pounds per square inch is built up. The brake pedal is then worked back and forth slowly a few times.

(4) The procedure for bleeding power brake control valve systems is comparatively simple. Before the bleeding operation begins, the brake accumulator must be charged. A bleeder hose is attached to the actuating cylinder bleeder valve. The free end of the bleeder hose is submerged in oil in a clean glass jar. The bleeder valve is then opened, and oil is metered through the power brake control valve (by working the foot pedals) until no more bubbles appear in the bleeder jar. The bleeder valve is then tightly closed, the bleeder hose is disconnected, and the dust cap is replaced. The system should be given a thorough operations check after bleeding.

d. Adjustment. Master cylinder brake systems usually incorporate an adjustment in the linkage. This adjustment may be used to change the length of the piston stroke. The adjustment of power brake control valves must be checked at periodic intervals. If adjustment is necessary, it should be made according to the handbook of instructions for the particular unit. The general procedure for adjusting typical types of power brake control valves follows:

(1) Two adjustments may be made on the external spring type; the low-pressure adjustment and the high-pressure adjustment. The low-pressure adjustment is always made first. It is made as follows: Attach a low-pressure gauge to the bleeder valve on the brake actuating cylinder, and open the bleeder valve. Screw in the low-pressure adjusting screw (fig. 58) until the gauge reads 10 to 15 pounds per square inch, depress the pedals halfway, and release. Screw the low-pressure adjusting screw out until the gauge shows 5 pounds per square inch, then turn this screw ¼ turn out and lock it. Close the bleeder valve and remove the gauge. The high-pressure adjustment is made with full operating pressure in the system. It is made as follows: attach a high-pressure gauge to the bleeder valve and open the valve. Place the high-pressure adjustment fulcrum approximately 2 inches from the point of connection to the brake linkage, depress the foot pedals all the way, and note the gauge reading. If the pressure is too low, move the fulcrum toward the low-pressure adjusting screw. If the pressure is too high, move the fulcrum in the opposite direction. Continue the adjustment until the pressure is within the correct limits for the unit. Close the bleeder valve, remove the gauge, and replace the dust cap. ***Caution:*** Do not move the fulcrum when it is under load.

(2) Adjustment of the internal spring type is accomplished by varying the stroke of the push rod. (See fig. 59.) Attach a high-pressure gauge to the bleeder valve and open the valve. With full operating pressure in the system, depress the foot pedal all the way and note the pressure gauge reading. If the pressure is too low, lengthen the stroke by screwing the stroke adjusting nut *away* from the cylinder. If the pressure is too high, screw the

adjusting nut toward the cylinder to shorten the stroke. Continue the adjustment until the pressure is within the correct limits for the unit. Close the bleeder valve, remove the gauge, and replace the dust cap. With the brakes in the full OFF position, the inlet valve lever adjusting screw should be turned in or out until the correct clearance between the end of the screw and the head of the bullet valve is obtained.

e. Maintenance problems. Malfunctioning of hydraulic brake systems may have many causes. In some instances it may be caused by conditions outside the hydraulic system. A few of the most common troubles pertaining to the hydraulic system are:

(1) *Locked brakes.* In some instances the increase in temperature may be sufficient to create a high enough pressure in the system to prevent release of the brakes from the parked position in the conventional manner. If the brakes cannot be released by applying a normal force to the foot pedal, open the bleeder valve and allow a few drops of oil to escape. Because of the incompressibility of the oil, this small volume will reduce the pressure enough to permit release of the brakes.

(2) *Brakes failing to remain parked.* Check all lines and fittings for leaks. If the parking assembly includes a ratchet, inspect the teeth for wear. If neither of the foregoing is the trouble, bleed the system. If the brakes continue to release, inspect the units for internal leaks.

(3) *"Grabbing" brakes.* This condition may exist if there is air in the system or if the maximum pressure metered by the brake control valve is too high. A defective brake de-booster may also cause the brakes to grab. If this is the cause of the trouble, replace the de-booster.

(4) *Insufficient braking action.* This may be caused by lack of oil or a lack of pressure. If this trouble is encountered in a brake control valve system, check the amount of fluid in the system and adjust the brake control valve. If encountered in a master cylinder system, first check the oil level in the reservoir. If this does not reveal the trouble, check for external and internal leaks.

(5) *Brakes failing to release quickly.* This fault is usually caused by weak return spring. Swelled piston packing may also cause this trouble. In a brake control valve system, this difficulty may be caused by a partially clogged return line.

SECTION VII

HYDRAULIC SYSTEMS

45. GENERAL. a. There are five general types of hydraulic systems:

(1) Electrically driven pump system.

(2) Power control valve system.

(3) Pump control valve system.

(4) Pressure regulator system.

(5) Open center system.

b. A typical system of each type is described in this section. Specific installations of each type of system may vary but the basic units and the principle of operation will be the same. In the study of these systems, frequent reference should be made to the previous detailed material on each unit.

46. ELECTRICALLY DRIVEN PUMP SYSTEM. a. Purpose. The electrically driven pump system is generally installed on smaller types of airplanes to operate all hydraulic mechanisms except the brakes.

b. Description. A typical system is shown in figure 64. It consists of the following units:

(1) An electrically driven power pump (par. 10) for operating the main landing gear, tail wheel, wing flaps, and gun chargers.

(2) A toggle switch for starting and stopping the electric motor which drives the pump.

(3) A double-action, piston displacement type hand pump (par. 11) for emergency operation and ground-checking.

(4) Poppet type selector valves (par. 31) for controlling the operation of the landing gear, tail wheel, and flaps. One selector valve controls the operation of the main landing gear and tail wheel; the other controls the operation of the flaps. Although both selector valves are built into the same housing, they are independent units. A check valve (par. 23) is built into the pressure port to each selector valve.

(5) Gun-charger valves (par. 32) for charging guns. These units are connected in parallel.

(6) Actuating cylinders (par. 14) for moving the mechanisms. There are two actuating cylinders for the main landing gear, one for the tail wheel, one for the flaps, and one for each of the four guns.

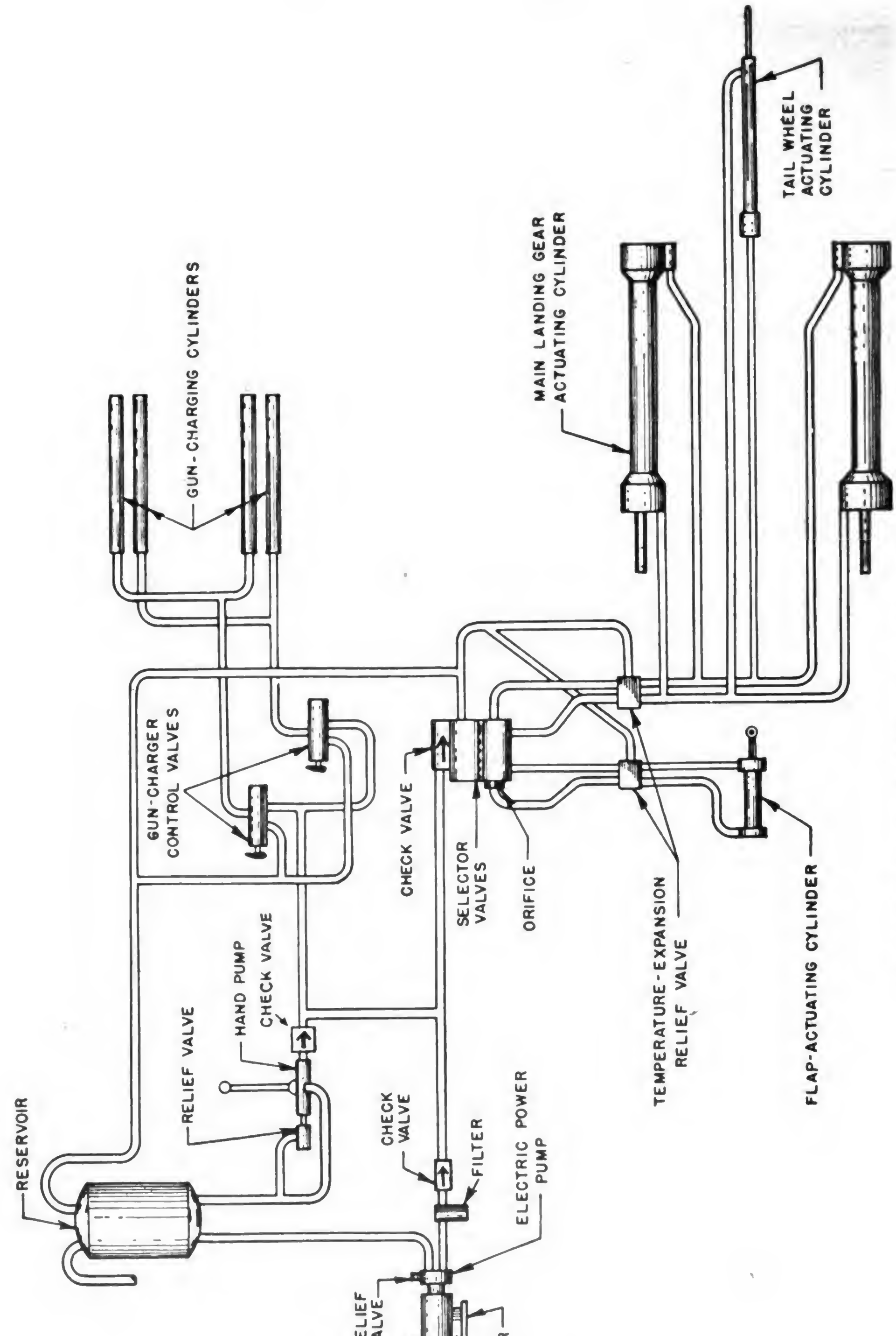


Figure 64. Typical electrically driven pump system.

(7) A power-pump relief valve (par. 34) to prevent the development of excessive pressure between the time the mechanism reaches the end of its stroke and the time the pilot turns the switch off and stops the pump.

(8) A hand-pump relief valve (par. 34) to limit the maximum pressure that the hand pump may produce.

(9) A reservoir (par. 8) which houses a supply of oil for the system.

(10) An orifice (par. 22) in the flap downline to prevent the flaps from going to the UP position too rapidly.

(11) A check valve (par. 23) in the pressure line from the power pump to prevent bypassing of oil through the power pump when the hand pump is operated.

(12) Compound temperature expansion relief valves (par. 34) to prevent the development of excessive pressures by increases in volume due to temperature change. These units are installed in both the landing gear and flap systems.

c. Operation. The general procedure for operating a mechanism in this type of system is to place the selector valve in the desired position and turn the toggle switch on. The switch is spring-loaded to return to the OFF position. It must be held on until the operation is complete. The switch should be held on several seconds after the mechanism has reached the end of its stroke, to insure that pressure has been built up in the actuating cylinder. The selector valve is then placed in the neutral position and the switch is released.

d. Maintenance problems. Typical troubles which may be encountered in the maintenance of this type of system, and possible causes and remedies, are listed in table I. External leaks and shortage of fluid are not listed as causes, although they may cause some of the troubles mentioned.

Table I. Troubles, causes, and remedies—electrically driven pump system

Trouble	Possible cause	Remedy
1. Pump does not develop any pressure.	Shear pin or shear linkage broken.	Replace power pump.
2. Pump does not develop enough pressure to operate the mechanisms.	Spring in relief valve broken.	Replace spring and readjust valve.
	Relief-valve setting too low.	Readjust relief valve.
3. Mechanisms creep when stopped in intermediate position.	Internal leak in actuating cylinder.	Replace piston packing.
	Poppet in selector valve not seating.	Clean unit to remove foreign matter; then check cam clearance.
4. Times of operation longer than specified.	Air in system.	Bleed the system.
	Internal leak in actuating cylinder or selector valve.	Stop leak as in 3.
	Worn gears in pump.	Replace pump.

Table I. Troubles, causes, and remedies—electrically driven pump system—Con.

Trouble	Possible cause	Remedy
5. Spongy action of hand pump.	Air in system.	Bleed system.
6. Hand pump operates too easily.	Internal leak in hand pump.	Replace packing. If leak continues, inspect check valves to see that they seat.

47. POWER CONTROL VALVE SYSTEM. a. Purpose. Like the electrically driven pump type, the power control-valve system is used in smaller types of airplanes to operate all hydraulic mechanisms except the brakes.

b. Description. A drawing of this type of system is shown in figure 65. It consists of the following units:

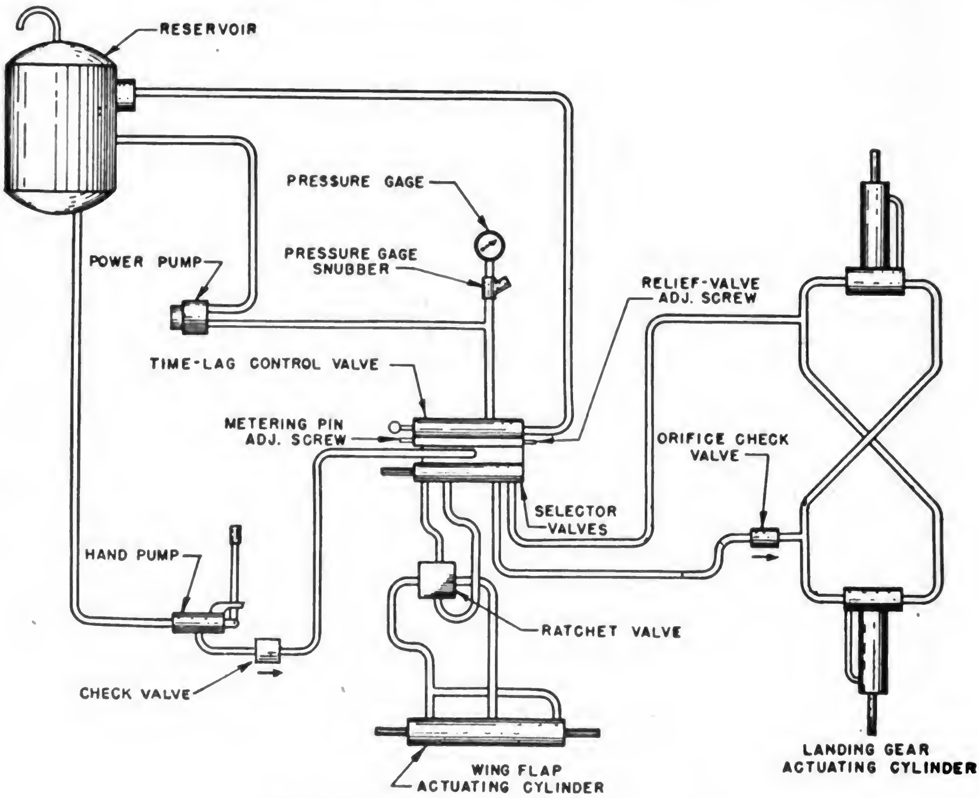


Figure 65. Power control valve system.

(1) An engine-driven power pump (par. 10) for operating the landing gear and wing flaps. This pump is mounted on the engine accessory section and will therefore operate all the time the engine is running.

(2) A time lag power control valve (par. 19) for unloading the pump. This unit must be manually closed, but it opens automatically after a given interval of time.

(3) A hand pump of the double-action piston rod displacement type (par. 11) for emergency operation and ground-checking.

(4) A compound piston type selector valve (par. 31) for controlling the operation of the landing gear and flaps. The pistons in this valve are not equipped with packing; therefore, they will not hold pressure indefinitely. Each piston is attached to an operating handle. If the unit is installed in a two-place ship, duplicate controls are installed in each cockpit and connected to the valve by a linkage.

(5) A ratchet valve (par. 37) which is installed in the flap system. Both flap alternating lines pass through this unit. Pressure is retained in the flap-actuating cylinder by this unit, even though the selector valve is of the "leak" type.

(6) A relief valve (par. 34) to limit the pressure developed by the pump after the mechanism reaches the end of its stroke and before the time-lag valve opens.

(7) A pressure gauge to show the pressure in the system. This unit is installed on the pressure manifold between the time-lag valve and the selector valve. A pressure-gauge snubber (par. 39) is installed in the line to the pressure gauge to prevent oscillation of the pointer.

(8) An orifice check valve (par. 24) which is installed in the landing gear upline. This unit restricts the flow of oil from the up side of the actuating cylinder (par. 14) and thereby keeps the landing gear from falling too rapidly.

c. Operation. (1) The general procedure for the operation of a mechanism in this type of system is first to engage the time-lag power control valve, then move the selector valve to the desired position. The time-lag valve will open automatically at the end of a given length of time. If the unit fails to open, pull on the handle.

(2) If the system incorporates a power-control valve without a time-lag feature, the procedure for operation is first to place the selector valve in the desired position and then engage the power control valve. This unit will open when pressure reaches the value for which the unit is adjusted. If the unit fails to open, bump the knob with the heel of the hand.

d. Maintenance problems. Table II gives a few of the typical troubles encountered with this type of system. Possible causes and remedies are listed opposite the troubles. Shortage of fluid and external leaks are not listed, but are often sources of trouble.

Table II. Troubles, causes, and remedies—power control valve system.

Trouble	Possible cause	Remedy
1. Time-lag valve opens before mechanism reaches end of its strike.	Time-lag valve out of adjustment.	Adjust time-lag valve.
	Cup on piston is leaking.	Replace cup.
	Mechanical binding.	Correct condition.
2. Time-lag valve does not open.	Metering valve is clogged or closed.	Remove and clean metering valve.
	Broken return spring in time-lag valve.	Replace spring.
3. Flaps "droop" when system is not being operated.	Internal leak in flap-actuating cylinder.	Replace piston packing.
	Broken or weak spring in ratchet valve.	Replace spring.
	Ball in ratchet valve not seating.	Clean unit thoroughly.

48. PUMP CONTROL VALVE SYSTEMS. a. General. This type system is essentially the same as the power control valve system. The only outstanding difference in the two types of systems is that a pump control valve (par. 17) is used instead of a power control valve.

b. Operation. The general procedure for the operation of a mechanism in this type system is to move the selector valve to the desired position, then hold the pump control valve handle in the DOWN position until the operation is complete. This handle is usually spring-loaded to return to the UP position.

49. PRESSURE REGULATOR SYSTEM. a. Purpose and use. Usually the pressure regulator system is used on larger type airplanes to operate all mechanisms, including the brakes. It is used on some smaller type airplanes.

b. Description. A schematic drawing of a system of this type is shown in figure 66. The system includes the following units:

(1) An engine-driven gear type power pump (par. 10) for operating the landing gear, wing flaps, cowl flaps, bomb doors, and brakes.

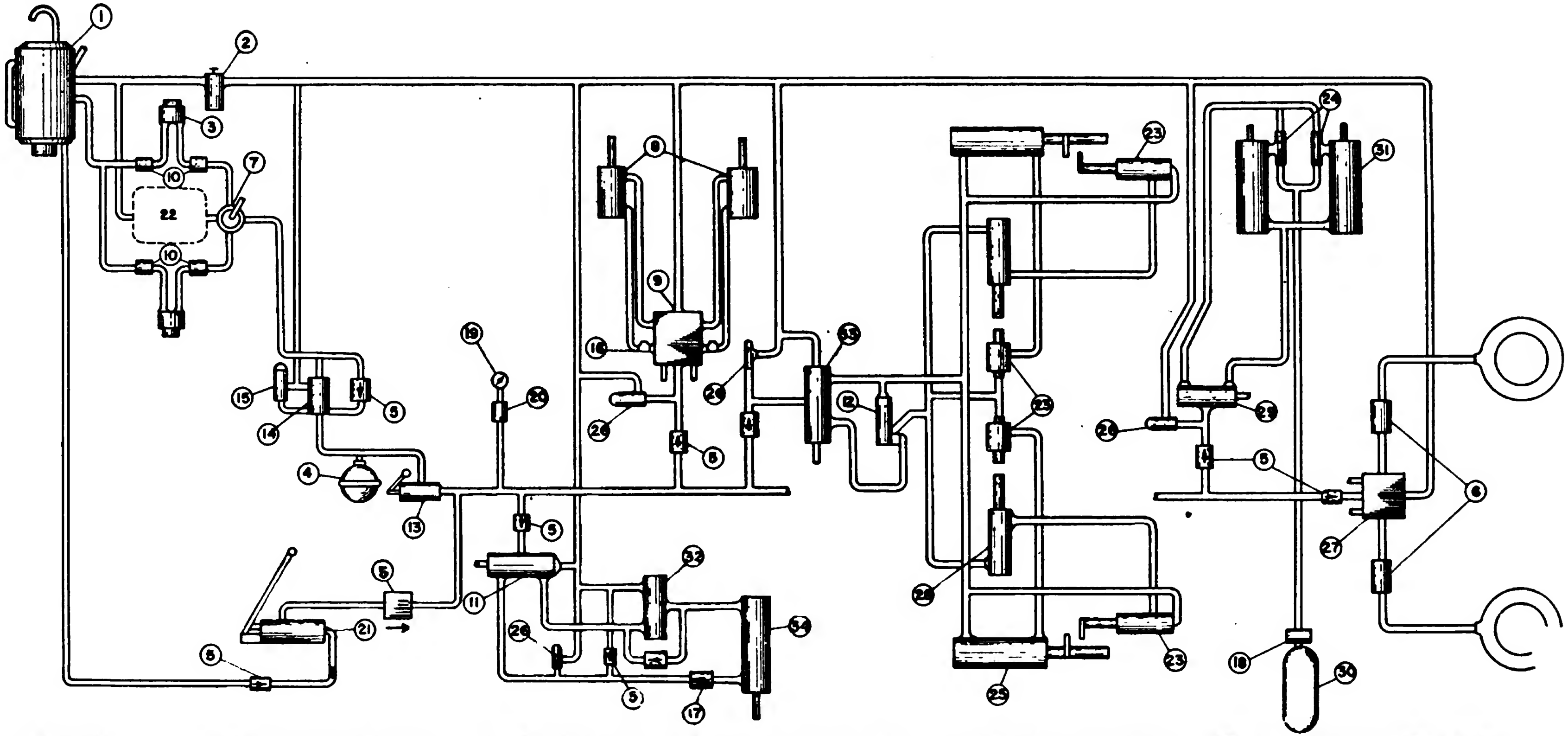
(2) A hand pump (par. 11) for emergency operation and ground checking.

(3) Line disconnect valves (par. 26) to facilitate engine or pump change.

(4) A rotor type power pump selector valve (par. 31) to direct oil from either power pump to the system. The output of the other pump is automatically directed to the gyro-pilot.

(5) A pressure regulator (par. 20) to unload the power pump. This unit also keeps the pressure within certain predetermined values.

(6) A system relief valve (par. 34) to prevent the development of excessive pressure if the pressure regulator fails to function.



1 RESERVOIR	7 POWER PUMP SELECTOR VALVE	13 BY-PASS CHECK VALVE	19 PRESSURE GAGE	25 LANDING GEAR ACTUATING CYLINDER	30 EMERGENCY AIR CYLINDER
2 CUNO FILTER	8 COWL-FLAP ACTUATING CYLINDERS	14 PRESSURE REGULATOR	20 ORIFICE	26 TEMPERATURE EXPANSION RELIEF VALVE	31 BOMB DOOR ACTUATING CYLINDER
3 POWER PUMP	9 COWL-FLAP SELECTOR VALVES	15 SYSTEM RELIEF VALVE	21 HAND PUMP	27 POWER BRAKE CONTROL VALVE	32 FLAP OVERLOAD VALVE
4 ACCUMULATOR	10 LINE DISCONNECT VALVES	16 VARIABLE RESTRICTOR	22 GYRO-PILOT	28 LANDING GEAR DOOR ACTUATING CYLINDER	33 LANDING GEAR SELECTOR VALVE
5 CHECK VALVE	11 WING FLAP SELECTOR VALVE	17 ORIFICE CHECK VALVE	23 SEQUENCE VALVE	29 BOMB DOOR SELECTOR VALVE	34 FLAP ACTUATING CYLINDER
6 DE-BOOSTERS	12 CROSS FLOW VALVE	18 RELEASE VALVE	24 SHUTTLE VALVE		

Figure 66. Typical pressure regulator system.

(7) A pressure accumulator (par. 12) to store fluid under pressure.

(8) A bypass check valve (par. 27) to prevent the charging of the accumulators during emergency operation of the hand pump or to permit charging the accumulators when desired.

(9) A pressure gauge to indicate pressure in the system. An orifice (par. 22) is installed in the line to the pressure gauge to reduce oscillations of the pointer.

(10) Piston type selector valves (par. 31) to control the operation of the mechanisms.

(11) A relief valve (par. 34) in each section of the system to prevent the development of excessive pressure due to temperature expansion.

(12) Actuating cylinders (par. 14) for moving each mechanism.

(13) Automatic cross-flow valves (par. 30) installed in the landing-gear system to allow the landing gear to extend evenly and rapidly.

(14) A flap overload valve (par. 36) to prevent lowering the flaps, to the full DOWN position, at excessive speeds.

(15) An orifice check valve (par. 24) installed in the flap downline to keep the flaps from going to the UP position too rapidly.

(16) Shuttle valves (par. 29) installed in the bomb door system to allow emergency operation of the bomb doors by air pressure.

(17) A cylinder and release valve for emergency operation of the bomb doors if the main system and the hand pump should fail.

(18) Power-brake control valves (par. 42) and de-booster valves (par. 42) to control the operation of the brakes.

(19) A reservoir (par. 8) to house a supply of fluid for the system.

(20) Variable restrictors (par. 22) in the cowl flap system to restrain the rate of movement of the cowl flaps.

(21) Sequence valves (par. 28) to cause the landing-gear doors to open before the landing gear starts down and to cause the landing gear to reach the full UP position before the doors start to close.

(22) A Cuno filter (par. 9) installed in the return line to remove foreign matter from the oil.

(23) The necessary check valves (par. 23), fittings, and tubing.

c. Operation. (1) The general procedure for operating a mechanism in this type of system is to move the selector valve to the desired position. When the mechanism has reached the end of its stroke and pressure has been built up in the pressure tank, the pressure regulator automatically opens and relieves the pump of load.

(2) Emergency operation of the bomb doors is accomplished by placing the selector valve in the OPEN position and opening the emergency release valve. Compressed air from the cylinder passes through the emergency line to the shuttle valve. This unit directs the air to the bomb door actuating cylinders, and the doors are opened.

d. Maintenance problems. A few typical troubles which may be encountered in servicing this type of system are listed in table III. Possible

causes and remedies are listed opposite the troubles. Shortage of fluid and external leaks are not listed, but are often sources of trouble.

Table III. Troubles, causes, and remedies—pressure regulator system

Trouble	Possible causes	Remedy
1. Pump will not develop pressure above that required for the automatic pilot.	Too much clearance between rotor and housing of power pump selector valve.	If rotor has adjusting nut, tighten nut. If not, replace selector valve.
	Valve may be in halfway position.	Place handle in proper position.
2. System pressure below specified value.	Pressure regulator out of adjustment.	Adjust regulator. If not adjustable replace.
3. No pressure developed in system when power pump is functioning properly.	Regulator stuck or held in open position.	Clean regulator if possible
4. Pressure from accumulator drops suddenly when position of selector valve is changed.	Internal or external leak in accumulator.	Repair leak or replace accumulator.
		Replace valve core.
5. Landing gear does not go to DOWN position smoothly and rapidly.	Cross-flow valve clogged.	Clean cross-flow valve.
6. Mechanisms creep when stopped in intermediate position.	Internal leak in actuating cylinder or selector valve.	Replace faulty piston packing.
7. Accumulator cannot be charged to specific pressure with hand pump.	System relief valve set too low.	Adjust system relief valve.
8. Erratic pressure-gauge reading at regular kick-out pressure.	No air in pressure accumulator.	Check accumulator for leaks. Replace if necessary.
	Check valve leaking badly.	Inspect check valve. Rework valve seat if necessary.

50. OPEN CENTER SYSTEM. In this type system, fluid circulates from the reservoir, through the pump, through the selector valves in the system, and back to the reservoir. There is no pressure in the system (except that due to friction) when no units are operating. The outstanding differences between this type system and other types of systems follow.

a. The open center system contains open center or automatic neutral selector valve (par. 31) instead of the conventional piston or poppet type selector valves. When these valves are in neutral the output of the power pump circulates through them to the reservoir.

b. These selector valves are connected in series instead of in parallel.

c. In an open center system the selector valve is the unit which relieves the pump of load when the mechanism reaches the end of its stroke.

SECTION VIII

INSPECTION AND MAINTENANCE OF HYDRAULIC SYSTEMS

51. GENERAL. **a.** Constant and thorough checking and adjustment are required to maintain any hydraulic system properly. Every unit and part in the system must function properly if the system is to operate correctly. To test the system or its parts, a power-driven pump is required. In most hydraulic systems the power pump is engine-driven. To test these systems without operating the airplane engine, an auxiliary source of pressure is needed.

b. Two standard auxiliary sources of pressure for testing hydraulic systems and units are in use. The gasoline engine-driven test stand (fig. 67) is used in the field or wherever electric power is not available. The electrically driven test stand (fig. 68) is used where electric power is available. Either type of stand may be used for testing a complete system. The electrically driven stand is more elaborately equipped and may be used to test units or sections of the complete system. If neither of the stands is available, an emergency stand may be constructed. The units incorporated in the emergency stand will be determined by the tests to be performed.

52. HYDRAULIC TEST STANDS. **a. Gasoline engine-driven stand.** The purpose of the gasoline engine-driven stand is to supply hydraulic pressure for testing hydraulic systems when electric power is not available. Its use for testing individual units is limited because the assembly does not have a reservoir.

(1) *Description.* The assembly pictured in figure 67 consists of a gasoline engine which is equipped with a constant speed governor, a variable volume hydraulic pump which is connected to the engine by a flexible coupling, a pressure compensator, a volume-control handwheel, a relief valve, a shut-off valve connected between the pump inport and outport, a pressure gauge, and two connector hoses. The smaller hose is the pressure hose, and the larger hose is the return hose. All units are mounted on a steel frame equipped with four pneumatic-tired wheels and a pulling tongue. Figure 69 is a schematic drawing of the hydraulic system of this test stand.

(2) *Preparation for use.* Before connecting the test stand to the airplane system, the pump case must be filled with the same type of oil as that used in

Figure 67. Gasoline engine-driven hydraulic test stand.

the airplane system. The gasoline tank should be filled with a good grade of gasoline which is free from dirt and water. Regular grade gasoline is recommended. Before starting the engine, both the pressure and the return hoses must be connected to the airplane system. The bypass shut-off valve should be opened to allow the engine to start without load.

(3) *Operation.* To start the engine, pull out the choke button, engage the crank at the flywheel, and pull up on the crank. *Do not* push down on the crank, for there is danger of a possible kickback. If the carburetor has run dry, considerable cranking will be necessary to start the engine. The choke button should be pushed in as soon as the engine starts. In cold weather the choke button should be pushed in gradually as the engine warms up. As soon as the engine is running smoothly, the shut-off valve should be closed. The output of the pump can be changed by means of the volume-

Figure 68. Electrically driven hydraulic test stand.

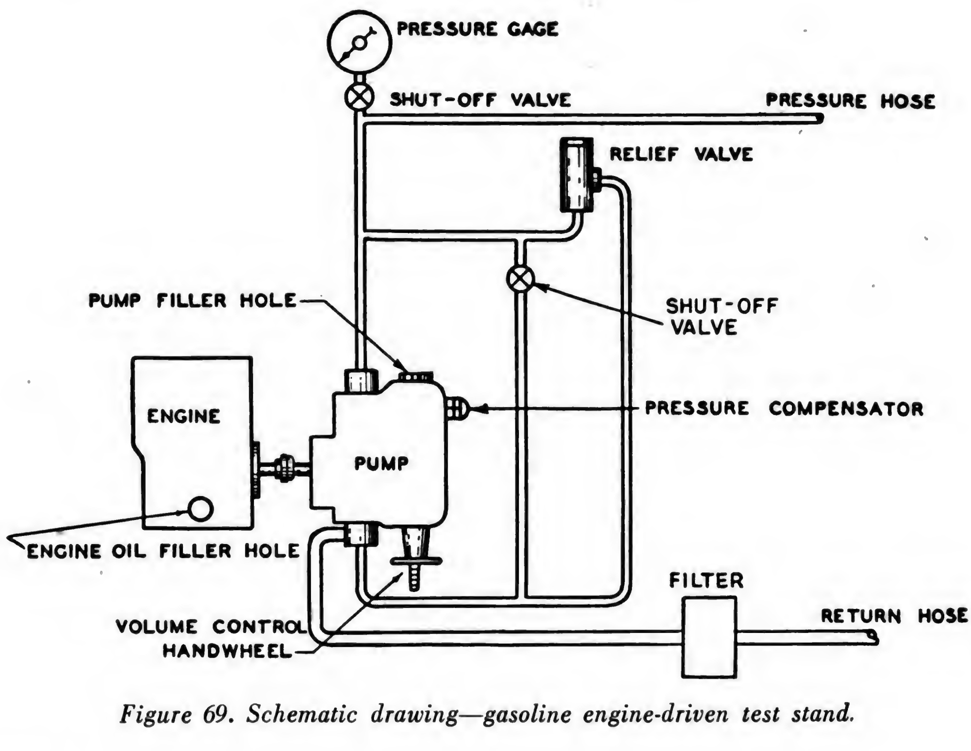


Figure 69. Schematic drawing—gasoline engine-driven test stand.

control hand wheel. The pressure compensator may be adjusted to cause the pump stroke to go to zero at the desired pressure. Pressure will then be maintained, but the pump will be delivering almost no oil. To adjust the compensator, the acorn nut must be removed and the lock nut loosened. Turning the adjusting screw in the clockwise direction increases the pressure setting. The relief valve functions only in case of faulty operation of the compensator. Both of these valves must be set at a higher pressure than the relief valve of the system being tested. The push button must be *held down* to stop the engine.

(4) *Inspection and Maintenance.* Before using the stand, check all hydraulic connections and the pump mounting bracket for tightness, check the setting of the pressure compensator and the relief valve, and check the supply of gasoline and oil. The crank case should be drained and refilled periodically.

b. Electrically driven test stands. Test stands of the electrically driven type are used for testing airplane hydraulic systems and units where electrical power is available. A test stand may be used also for testing individual units or a part of the system.

(1) *Description.* The unit pictured in figure 68 consists of an electrically driven power pump, reservoir, two filters, relief valve, pressure accumulator, tachometer, speed-control wheel, starting switch, phase-reversing switch, four shut-off valves, needle valve, and connector hoses. The smaller hose is the pressure hose. Some test stands have a selector valve which allows two-way operation of sections of the main system without use of the selector valves on the airplane. These units are all mounted on an enclosed frame, which is mounted on wheels and may be moved readily from place to place. A schematic drawing of the test stand hydraulic system is shown in figure 70. The power pump is of the gear type. It is belt-driven by the electric motor. Valves *A*, *B*, *C*, and *D* are standard globe type shut-off valves. The relief valve is adjustable by means of a "hex" knob on the instrument panel.

(2) *Preparation for use.* Before connecting the test stand to the airplane hydraulic system, be sure the test stand is specified to contain and does contain the same type of hydraulic fluid as that used in the airplane system and that the pump case is full of fluid. The reservoir should contain a sufficient amount of this oil. The two connector hoses should be connected to the airplane hydraulic system or section of the system to be tested. The test stand relief valve setting should be checked. This relief valve must be set at a higher value than the relief valve in the airplane system. The proper globe valves should be opened or closed to give the desired flow of fluid. If a leak test is to be made, the accumulator should be built up to test pressure.

(3) *Operation.* The test stand is put into operation by plugging the extension cord into a 220-volt, 60-cycle line and turning the starting switch on. This switch is located on the left-hand side of the front panel. The

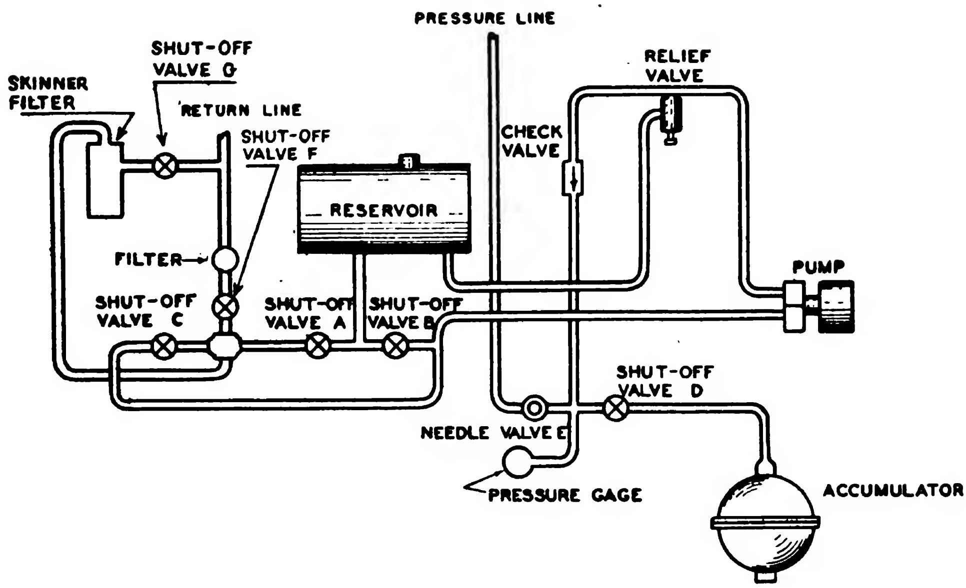


Figure 70. Schematic drawing—electrically driven test stand.

direction of rotation can be controlled by the phase-changing switch located over the starting switch. The speed of the motor can be adjusted by the handwheel located on the left side of the instrument panel. This speed is indicated by the tachometer on the right side of the instrument panel. Do not try to force the handwheel beyond the speed shown on the nameplate or the belt or mechanism, will be harmed. The operating handles of the globe valves and the needle valve are located on the bottom of the instrument panel. The globe valves *A*, *B*, and *C* (fig. 70) are used to determine the path of the oil through the system. With valves *A*, *B*, *D*, *F*, and *G* closed and valves *E* and *C* open, the stand reservoir is "cut out" of the system and the airplane reservoir is supplying oil for the test. Valve *G* is to be kept open and valve *F* closed at all times unless the Skinner filter is not operable. If the Skinner filter is not in operating condition, the Cuno filter may be used by opening valve *F* and closing valve *G*. If it is desired to have the test stand reservoir supply oil, close valves *C* and *D* and open valves *B* and *E*. If the system is being filled and the oil is not expected to return to the stand reservoir, valve *A* must be closed. The needle valve *E* controls the volume of oil delivered to the system or unit being tested. The accumulator should be used only to check a system or a unit for leakage. This accumulator should never be charged to greater than 1,000 pounds per square inch pressure. The initial charge of air is 250 pounds per square inch. To charge the accumulator with air, open valves *D* and *E* and disconnect the pressure hose. To charge the accumulator with fluid, close valves *A*, *C*, and *E*, and open valves *B* and *D*. With the relief valve set at 1,000 pounds per square inch, start the motor and allow it to run until the relief valve "kicks out." Shutting off valve *D* will hold the pressure in the tank until it is needed.

(4) *Inspection and maintenance.* Check the hydraulic system for loose connections. Be sure that the test stand relief valve is set at a higher pressure than the relief valve in the airplane system. The hydraulic pump should be inspected periodically. The two V-pulleys on which the belt is mounted should never be more than 1/8 inch out of line. If necessary, align the pulleys. Bearings should be lubricated according to instructions. *Do not overlubricate.* If grease should get on the belt or pulleys, use lacquer thinner or a clean cloth to remove it. *Never use gasoline on the belt.* The stand should be operated over its entire speed range at least three times a week.

c. Precautions. (1) Before connecting the test stand to the airplane hydraulic system, be sure the oil in the test stand is of the same type as the oil in the airplane system. These stands will be tagged to show the type of oil they contain. The test stand must be thoroughly flushed each time the hydraulic oil is changed. For flushing, use a mixture of one part benzine and one part dope-and-lacquer thinner. *Improper flushing will contaminate the airplane system and may result in damage to equipment and loss of life.*

(2) When testing a system or unit, *test thoroughly and carefully.* Failure of a single unit may render the entire hydraulic system useless. Instructions concerning testing procedures and test pressures should be followed carefully. *Don't guess.*

(3) Contact with moving hydraulic mechanisms may result in serious injury. Before operating any hydraulic equipment with the test stand, *be sure* all personnel are clear of the mechanism to be operated. If the landing gear is to be retracted, be sure the airplane is properly supported before retraction.

(4) Before connecting the test stand to the system, be sure all selector valves are either in the neutral positions or in a position corresponding to the position of the mechanism. If the ship is not to be supported during the test, lock or safety the landing-gear selector valve in neutral.

(5) Do not operate the test stand pump for long periods of time. Turn the motor or engine off unless the stand is actually in use.

(6) When testing a pressure regulator, *do not* open the needle valve *E* all the way, or the pressure gauge may be damaged.

d. Testing hydraulic units. (1) *General.* General testing procedures for a few typical classes of units will be considered in this section. Specific instructions for testing particular units may be found in Technical Orders. These instructions should be consulted before testing the unit. Routine testing of the operating pressure of such units as pressure regulators, relief valves, etc., can usually be done without removing the unit from the system. For this purpose either type of test stand may be used. If the unit is removed from the system for testing, the electrically driven test stand must be used.

(2) *Leaks.* These tests may be made with the use of the pressure tank on the electrically driven test stand—if the test pressure is not too high. Maxi-

mum allowable leakage for a given unit is specified in the applicable Technical Order. Leakage less than this amount will not be cause for repair or replacement.

(3) *Check valves.* These valves are tested with the electrically driven test stand. Apply test pressure to the outport of the valve and hold for 5 minutes. No oil should come out of the inport.

(4) *Relief valves.* If the relief valve cannot be tested in the system, remove the valve and connect the inport to the pressure hose and the outport to the return hose of an electrically driven test stand. Build up the test pressure to a value slightly below the relief-valve setting and hold for 5 minutes. There should be no leakage through the unit. Leakage will be indicated by a decrease in the pressure shown by the test stand pressure gauge. Disconnect hoses and connect the pressure hose to the outport. Apply the correct test pressure and hold for 5 minutes. There should be no leakage.

(5) *Selector valves.* (*a*) These units are tested by applying test pressure to each of the four ports in turn. Apply pressure only when the valve is in the neutral position. Connect the pressure hose of an electrically driven test stand to the pressure port of the valve. Start the power pump and adjust the test stand relief valve to "kick out" at the test pressure of the unit. Put the selector valve in neutral and open valve *E*. When the test stand relief valve "kicks out," stop the power pump. Hold pressure on the valve for 10 minutes; there should be no leakage during this time. The foregoing procedure should be repeated for the return port and each of the alternating ports.

(*b*) Units containing packing cups or seals are also given a low-pressure test. This test will show leaks which would not be evident at high pressure because of the force holding the packing against the cylinder wall.

(6) *Actuating cylinders.* With ports open, move the piston back and forth in the cylinder to check for freedom from binding. If the cylinder is equipped with swivel joints, check these joints for freedom of movement. Then apply test pressure to each port in succession. Hold test pressure for 5 minutes and check for external and internal leaks. Watch particularly for leaks around the piston rod as the piston is forced in. Actuating cylinders are usually subjected to a low-pressure test. Test pressures used will depend on the unit being tested.. Correct values for specific units may be found by consulting Technical Orders.

53. OPERATION CHECK OF HYDRAULIC SYSTEMS. a. Procedure. (1) An operation check may be performed with the system pump or either type of test stand. Before beginning the operation check, the airplane should be properly supported so as to allow operation of the landing gear without harm to the airplane. Check the oil level in the reservoir and inspect all units and lines for external leaks. If it is not convenient or safe to

use the system pump, a test stand must be used. Connect the test stand pressure and return lines to the corresponding lines in the system. These connections are usually made at the fire wall. Charge the test stand accumulator and apply pressure to the system by opening the correct valves. Note whether or not there is a pressure drop on the test stand pressure gauge. If the pressure drops, check all lines and units for external leaks. Trace all leaks to their source and eliminate the cause. If there is a pressure drop and no external leak is found, test sections of the system until the internal leak is found.

(2) Start the test stand pump and adjust the output to agree with that of the system power pump. Set the test stand relief valve or pressure compensator at a higher pressure than the system relief valve. The airplane system may now be operated in the usual manner.

(3) Operate all mechanisms through at least two cycles. Check the time and pressure required for operation against the time and pressure specified as normal. Note whether or not the time required decreases with successive operations. Stop all mechanisms in an intermediate position and note whether or not the mechanism creeps. The operating pressure of unloading valves may be checked by putting all selector valves in neutral. If the system has a pressure regulator, relief valves may be tested by using the hand pump or by removing them from the system.

(4) Check the position indicators against the position of the mechanism through a complete cycle. Check the warning devices to see that they go on or off at the correct time. Check the charge of air in the accumulator. If the charge is low, check the accumulator for leaks.

(5) If an electrically driven test stand is being used, the system reservoir or the stand reservoir may be used to supply the oil. If the test stand reservoir is being used, connect a hose to the airplane reservoir vent line. Place the other end of this hose in a container. This will catch any overflow due to excessive input from the test stand reservoir.

b. Interpretation of results. If the time required for operation is more than that specified as normal, there may be an internal leak in that section of the system or there may be air in the system. If the time of operation decreases with each cycle, air is being worked out of the system. "Spongy" action of the hand pump is also an indication of air in the system. Excessively easy operation of the hand pump is an indication of an internal leak in the pump. If the pressure attained with the power pump fluctuates, there may be air in the system, or the oil supply in the reservoir may be low. If the mechanism operates with a jerky motion, binding or fouling of the linkage is indicated. If the system is equipped with an accumulator and the pressure drops to zero when a selector valve is changed (when the power pump is not operating), the air has probably leaked out of the accumulator. If the accumulator cannot be charged to the operating pressure, the pressure regulator is probably set too low.

c. Elimination of troubles. Methods of eliminating a few of the troubles which may be found when making an operation check will be considered. Other troubles or combinations of troubles may be found. Any serious trouble which is found must be eliminated before restoring the airplane to flying status.

(1) *External leaks.* If the pressure drops during a leak check, first inspect all lines and units for external leaks. If an external leak at a connection is found, tighten the fitting. Do not tighten it excessively. If tightening does not stop the leak, disconnect the fitting and inspect the flare for cracks and imbedded grit. If a packing or gasket is leaking, tighten the packing nut or bolts. If the leak continues, the packing or gasket must be replaced. Disassemble the unit only enough to replace the faulty packing or gasket. Units should not be disassembled in the open. Wash all parts carefully before reassembly.

(2) *Internal leaks.* If an internal leak is found, localize the trouble by testing sections of the system. When the section containing the leak is located, test the units in the section. Remove the faulty unit, replace the leaking cup or seal, test the unit, and reinstall the unit in the system if the leak has been stopped.

(3) *Air in system.* If air is found in the system bleed it by operating all mechanisms. It may be necessary to operate all mechanisms through several cycles to remove all the air.

(4) *Faulty linkage.* If linkage is binding or fouled, repair or replace the faulty part of the linkage. Care should be exercised in straightening any bent linkage.

(5) *Low air pressure in accumulator.* If the charge of air in the accumulator is low, first check for an internal leak. If this is not the trouble, check for an external leak.

(6) *Incorrect operating pressure.* If the accumulator cannot be charged to operating pressure, first check the oil level in the reservoir. If this is not the trouble, check the setting of the pressure regulator. If the setting is not correct, adjust the valve. Some regulators are not adjustable. These will have to be replaced.

54. VALVE ADJUSTMENT. a. General. Units such as pressure-control valves, unloading valves, and some flow-control valves are usually adjustable. The opening pressure of each unit is checked periodically. If the hand pump is used to check the opening pressure of a unit, the handle must be operated very slowly to get the correct opening pressure. If the unit has an external adjusting screw, turning this screw in will raise the opening pressure of the unit, and turning the screw out will lower the opening pressure. Adjustment of some units is accomplished by inserting washers or shim stock between the spring and the housing to raise the opening pressure, or by removing shims or grinding off the spring to lower the opening pressure.

b. Relief valves. When adjusting relief valves in a system, adjust only one valve at a time. Back out the adjusting screw of the valve to be adjusted and turn the adjusting screws of all other relief valves in. Start with the valve having the highest opening pressure and progress in descending order to the valve having the lowest opening pressure. Screw in the adjusting screw until the pressure indicated on the pressure gauge is that required. Take several readings and consider the average as the setting of the valve. If there is a power-control valve in the system, it must be held closed and must be adjusted last.

c. Pressure switches. The pressure warning switch may be adjusted by tightening the cap. An external adjusting screw is provided on some units. The direction the cap or adjusting screw is turned will depend on whether the unit is used as a warning device to show high or low pressure. The pressure switch is adjusted by removing the cap on the end nearest the switch and turning the adjusting nut in or out. Turning the nut in raises the operating pressure, and turning the nut out lowers the operating pressure.

d. Gun-charger control valves. To adjust the gun-charger control valve, remove the plug from the end of the plunger and turn the adjusting screw in or out with a screw driver until the unit opens at the desired pressure. Turning the screw in raises the opening pressure, and turning the screw out lowers the opening pressure.

e. Metering valves. Adjust the metering valve by turning the metering pin in or out. Turning the pin in decreases the speed of operation and therefore increases the time required for the movement. Turning the screw out has the opposite effect.

f. Flap overload valve. Adjustment of the flap overload valve is made to allow oil to pass from the actuating cylinder to the return line at a given pressure. If this adjustment is made, no adjustment for the pressure at which the inlet port is closed is necessary. Turning the adjusting bolt in raises the opening pressure, and turning the bolt out lowers the opening pressure.

55. INSPECTION OF HYDRAULIC LINES. a. General. Failure of a single line or fitting may render the entire hydraulic system inoperative. Therefore, all lines should be carefully inspected at periodic intervals. Metal lines should be checked for leaks, loose anchorage, restrictions, and worn spots. Flexible lines should be checked for deterioration and soft spots. See that all flexible lines are held clear during operation of the mechanism. These lines should be kept free of oil and grease. Clean flexible lines with denatured alcohol.

b. Removal and replacement. Defective lines should be replaced. Replacement should be made with lines of the same size and material as the original lines. If the lines being replaced contain any bends, use a tube bender to shape the new line like the original line. Inspect the shoulders on fittings for scoring and grit before installing tubing. Use a thread lubri-

cant only on male threads. It should never be necessary to use a wrench more than 5 inches long. Do not tighten more than the amount prescribed for the size fitting being tightened. Band all new tubing light blue, yellow, light blue. The bands should be glued on, then coated with moistureproof lacquer.

c. Emergency installation. In some instances, tools for emergency installation of lines are carried in the flight engineer's tool kit. In this case, emergency installation of some hydraulic lines may be made while the ship is in flight. It will be necessary, however, to rob one section of the tubing to repair another section.

56. HYDRAULIC FLUIDS. a. Types and specifications. Two types of oil are used in hydraulic systems installed in airplanes. It is essential that the correct type of oil be used when servicing a system. To avoid errors, each system must be marked clearly to show the type of oil used in the system. Under no circumstances should a system be serviced with a type of oil different from that shown on the instruction plate.

(1) *Fluid, hydraulic, Specification 3586.* This oil is composed of castor oil and alcohol. It is supplied in two grades, light (grade C), and heavy (grade A). Grade C oil is normally used. In case excessive leakage or seepage is encountered with grade C in hot weather, grade A may be substituted. This fluid contains a blue dye which aids in identifying it.

(2) *Fluid, hydraulic, petroleum base, Specification 3580.* This oil is made from petroleum. It is supplied in two grades: light and medium. The medium grade corresponds to SAE 34 commercial oil. Medium grade oil is used unless the temperature is consistently 0° F. or below. This fluid contains a red dye to aid in identifying it.

(3) *Fluid, hydraulic, Specification AN–VV–O–366A.* This oil is an all-purpose, one-grade mineral oil which may be used at temperatures above minus 75° F. It may be used in all systems in which AAF Specification 3580 fluid is used. If the shock struts of an airplane are filled with this oil, the following statement will be stenciled with red paint on the outside of the strut: "Strut filled with AN–VV–O–366A hydraulic fluid."

(4) It is possible that hydraulic fluid may be made available in containers marked AN–VV–O–366. For all practical purposes, this oil is identical to AAF Specification 3580, *medium grade,* and will be used according to directions for AAF Specification 3580.

b. Cleanliness. (1) Every precaution should be exercised to prevent contamination of hydraulic oil. Storage containers must be kept sealed. All handling equipment must be kept clean and should be used only for hydraulic oil. Do not leave containers or the reservoir open any longer than necessary, since dust and grit in the air may get into the oil. Oil that has been exposed to dust contamination should be filtered before re-use. Filtering will remove sludge as well as metal flakes, dust, and grit. When cleaning a unit or a system, the proper cleaning agent should be used. If fluid,

hydraulic, castor oil and alcohol is used in the system, clean with butyl alcohol or denatured alcohol. If fluid, hydraulic, petroleum base, is used, clean with kerosene or naphtha.

(2) If the two types of hydraulic fluids become mixed a heavy gum will result which will be deposited throughout the system and cause many of the units to become inoperative. Therefore, when fluids become inadvertently mixed, it is necessary to remove all of the packing rings installed in the hydraulic units affected and flush the units and interconnecting lines with a neutralizing agent consisting of one part benzene, and one part dope and lacquer thinner. New packings must then be installed throughout.

57. HYDRAULIC PACKING RINGS. a. General. Several types of packing rings are installed to seal pressure in *hydraulic* units. Proper handling and installation of these seals is essential for the proper operation of the hydraulic system. One small nick or scratch on a seal may cause the failure of the unit in which it is installed.

b. Shape. The cross section of approved packing rings may be shaped like a "V," "U" (cup-shaped), or "O" (round ring). Installation procedures for the various types are discussed in paragraph 58.

c. Material. Only a few compounds are approved for use as packing rings. Rings of these materials *only* will be installed. Technical Orders should be consulted to determine the material to be used.

(1) As a general rule, all black rings with no color markings are intended for use with AAF Specification 3580 (or AN–VV–O–366A), regardless of shape. Brake cups will have red band stripes on the heel of the cup when intended for use in red colored hydraulic fluid (Spec. 3580 or AN–VV–O–366A) and blue band stripes when intended for use in blue colored hydraulic fluid. (Spec. 3586.)

(2) *Garlock.* V-rings of this material intended for use with red hydraulic fluid may be identified by irregular red dots on the outside of the heel. Those for use with blue hydraulic fluid will have a blue band around the heel.

(3) *Linear.* The approved material of this type is for use in red hydraulic fluid. V-rings of this compound may be identified by an "L" molded in the "V" of the ring.

(4) Other approved "V" type packings may be marked with a raised, molded diamond, "M," or "GN" in the "V" of the ring. O-shaped rings do not have these markings. Care should be exercised not to mix "O" type rings. rings.

58. MAINTENANCE PROBLEMS. a. Replacement of seals. The general procedure for replacing all types of packing rings is the same. Disassemble the unit only enough to replace the faulty packing. Be sure the packing is of the correct size and material. Never substitute packing of a different material for the specified packing. Visually inspect each ring for cuts, nicks, or flaws before installing. Do not install the ring if any of the

foregoing defects are present. Prior to installation, immerse the packing in the type fluid in which it is to be used. Do not use sharp instruments when installing or removing packing. Do not stretch rings more than is necessary.

(1) *"V" and "U" type rings.* Install each ring individually, making sure that each ring is seated. *Do not* install rings in sets. If the packing must cross sharp edges or threads, use shim stock to protect the packing. The shim stock (0.003–0.010 inch) is rolled and placed over the threads. The packing is then installed and the shim stock is pulled out. If the unit has an adjustable packing gland, adjust the gland nut until the "V" ring stack is set firmly together (but not squeezed); then loosen the gland nut to the first lock point (not to exceed one-sixth turn). If the unit does not have a gland nut, metal shims of graduated thickness may be inserted behind the adapters to hold the packing firmly in place. If possible, check the unit for free operation by hand before applying hydraulic pressure to the unit.

(2) *"O" type rings.* These rings usually require no adjustment on installation. They should be protected against scratching. After installation, check to see that the ring is of the proper size to give a "squeeze" in the installed position.

b. Resurfacing valve seats. The seats of ball and cone type valves only may be resurfaced, and these only in case of minor abrasions. Slide, spool, or piston valves must not be lapped. Any condition which would be cause for relapping is sufficient cause for replacement.

(1) *Cone type valves.* In resurfacing the seat of this type of valve, the cone is used as the grinding tool. Obtain a round stick slightly larger than the inside diameter of the cone and force the cone firmly down on the end of the stick. Apply a thin coating of very fine grinding compound to the outside of the cone; then place the cone on the seat and twirl it rapidly between the palms of the hands. (A combination rotary and tapping motion should be used to avoid ringing the seat.) The resurfacing process should not be continued long enough to widen the seat appreciably. Wash the valve thoroughly to remove all traces of grinding compound, install a new cone, and reassemble the unit. Test the unit before installing it in the system.

(2) *Ball type valves.* The process for resurfacing the seat of this type of valve is essentially the same as the process just described. The ball is soldered in the end of a piece of tubing which has an inside diameter slightly smaller than that of the ball. Grinding is done in the manner previously described. A new ball must be installed after the seat is resurfaced.

59. CAUSES OF POWER-PUMP FAILURES. The most frequent causes for power-pump failures follow with recommended corrective measures.

a. Abrasive particles in the fluid stream causing excessive pump wear and overheating with subsequent seizure of the moving parts of the pump and drive coupling failure. When this condition exists it is advisable to

flush the system and to exercise greater care thereafter in handling and storage of hydraulic fluid to prevent the entrance of foreign particles into the fluid reservoir.

b. Binding loads placed on the pump drive coupling resulting from uneven tightening of the mounting studs. When installing a new pump all mounting studs must be drawn down evenly.

c. Air lock (resulting from a low reservoir fluid level or air infiltration in the suction line leading to the pump) causing the pump to seize for lack of lubrication. In such an instance, the drive coupling will again fail. To prevent air infiltration, it is necessary to check the suction line for leakage with particular attention paid to disconnect fittings. To prevent air lock from low reservoir fluid level, it is necessary to check the fluid level frequently. In installations where no sight gauge is incorporated on the reservoir and where a screen is placed in the reservoir filler neck, this screen may become fouled with dust and debris to such an extent that when fluid is poured into the neck, the fluid will dam up on the screen giving the appearance of a filled reservoir when in reality the fluid level may be dangerously low. Hence, it is necessary to remove any collection of foreign material from the screen before filling the reservoir.

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